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TWENTY-FOURTH REPORT

OF THE

STATE ENTOMOLOGIST

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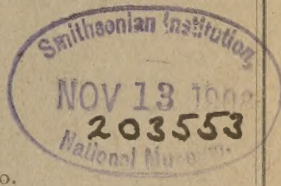
Noxious and Beneficial Insects

OF THE

STATE OF ILLINOIS

THIRTEENTH REPORT OF S. A. FORBES

BLOOMINGTON:
PANTAGRAPH PRINTING AND STATIONERY CO.
Printers, Binders and Stationers
1908







Injuries caused by Elm Twig-girdler (*Oberea ulmicola* Chittenden).

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Note.—The articles of this report have all been previously printed in the Bulletin of the Agricultural Experiment Station with the exception of that on the elm twig-girdler, on pages 118-134, which is now published for the first time. Plates IX., X., and XI. of this report are also here first printed, the others having been already once used in the experiment station articles, except Plate VIII. and the frontispiece, which were printed in illustration of Article I of Volume VII. of the Bulletin of the Illinois State Laboratory of Natural History.

INJURY TO CORN BY THE TIMOTHY BILL-BUGS (*SPHENOPHORUS* SP.).

In a general article on "The Corn Bill-bugs in Illinois," published in my Eleventh Report as State Entomologist (pages 1-26), a brief account was given of observations made in fields near Taylorville, Christian county, in 1902 (page 7); but the data in my possession concerning injuries to corn at this place and their relation to previous crops and to the history of the land, were not fully utilized in that paper. Our observations and correspondence have made it evident for some time that bill-bug injury to corn is imperfectly appreciated by corn growers and but little understood by them, and it consequently seems desirable that the careful work done on this insect injury near Taylorville should now be fully reported and thoroughly discussed.

June 26, 1902, Mr. D. S. Dalbey, a senior agricultural student in the University of Illinois, sent me the following note:—

"I have received from my father, Wm. M. Dalbey, of Taylorville, Illinois, some specimens of corn plants affected by the corn bill-bug. The land on which the infested corn was grown is timothy sod plowed in April of this year, and is located two miles northeast of Taylorville, on my father's farm. The damaged area covers forty acres, and the extent of the damage involves about half the stand. The plants affected are not dead, but have a sickly yellow color, and the leaves are punctured with holes."

I further learned that this land had been in timothy for the four years preceding, and the year before that in wheat. Clover and timothy had been originally sown together, but the clover ran out and the crop was practically pure timothy by 1901.

EXAMINATION OF INJURED FIELD.

June 30, 1902, I sent Mr. E. S. G. Titus to Taylorville with instructions to make a careful study of the condition of the infested field and to collect information for a comparison of its agricultural history with that of other fields of corn in its neighborhood, the object being to ascertain the full effect of bill-bug injury to corn on uplands, and to discover any differences in respect to this injury due to differences of agricultural management.

This work was done by Mr. Titus with characteristic thoroughness, intelligence, and skill. On his first visit, made June 30, he platted the Dalbey field, selecting and marking 650 hills which had been more or less injured by corn bill-bugs. On another visit, August 10 and 11, he made notes on the condition of these hills, and

October 2 and 3 he carefully examined them with reference to the condition of the stalks and the number and quality of the ears, in comparison with like facts concerning uninjured hills in the same field. Observations were also made on the condition of fields of corn on other farms of the neighborhood. The data thus obtained have since been summarized and tabulated for comparative study, and the materials are thus in hand for a fuller study of *Sphenophorus* injury to this crop than has ever before been reported.

DISTRIBUTION OF INJURY.

The injury to the corn in the Dalbey field was very uneven. In one corner almost every stalk on several acres had been damaged, while in other parts from 25 to 50 per cent. of the plants had been attacked. The distribution of the injury seemed not affected by the lay of the land or the moisture in the soil, there being more injury on low moist ground at one side of the field and less on similar ground at the other side than there was on the higher and drier ground.

THE INJURIOUS SPECIES.

The species of *Sphenophorus* actually responsible for this mischief was not definitely ascertained, the beetles having all disappeared from the field; but as the larva of *Sphenophorus parvulus* was common in the bulbous roots of timothy on adjacent premises, and as the old timothy bulbs still present in the injured corn field had been similarly hollowed out by bill-bug larvæ the year before, the probability is strong that this species was largely concerned in the injury under observation.

THE INJURY TO TIMOTHY.

Fields of timothy near by, which had been in that crop for three or four years in succession, had at this time from 50 to 75 per cent. of the bulbs more or less injured and infested, many of them containing larvæ ranging in size from those evidently but just hatched to those large enough to fill the whole timothy bulb. In fields but two years in timothy, on the other hand, from 10 to 20 per cent. of the bulbs were infested. The injured plants were inclined to throw out suckers at the base and also at the first joint above the ground. Where the bill-bug larva had eaten out all the substance of the bulb, it had often drilled into an adjacent bulb, and was found feeding therein. Some larvæ were seen just cutting their way out of the first bulb, and others in the act of boring into the second, a part of

the body in each. The effect of this amount of infestation on the timothy crop itself must certainly have been considerable, and the conditions were, of course, unusually dangerous to the corn crop following.

THE INJURY TO CORN.

The injury to corn had resulted variously, the differences being probably due to the age of the plant when injured, and to the number of punctures made in a single stalk. In many cases, as will be presently shown, the stalk had been killed, doubtless when the plant was still quite young. In other cases the stalk, though nearly or quite full grown, had fallen to the ground in consequence of a deficient root development, brace-roots being indeed practically lacking. Injured stalks were also smaller than normal just above the ground and at the joints higher up, and were likely to lean from the base or to bend at the weakened joints. A considerable percentage of the stalks in hills which had been infested had never formed the ear (at least 33 per cent. of these stalks being barren, as against 4 per cent. in uninfested hills), and on a much larger percentage of them the ear was either a small nubbin or imperfectly filled out. It was the owner's opinion that the worst-infested parts of the field averaged about twenty bushels of corn to the acre, and that the part not infested yielded from forty-five to fifty-five bushels.*

*A letter received from Mr. H. L. Jones, of Geneva, Ill., since this manuscript was prepared, makes mention of an effect of bill-bug infestation which has not previously been noticed, and describes also his method of diminishing the damage. He says: "I had a rather expensive experience with bill-bugs last season on a pasture plowed in spring. They appeared when the corn was four to six inches high, and crippled it badly in spots so that the injured inner leaf would break over and curl up, thereby preventing the next inner leaf from coming out and thus dwarfing the stalk. I immediately put men and boys into the field, who replanted the destroyed hills and picked the curled tops from all the damaged stalks, in this way saving nearly all the crop. This corn husked seventy bushels per acre where I am sure that it would have yielded eighty bushels but for the damage sustained. If the curled leaves had not been picked from the tops of the plants, I think that the crop would not have been more than fifty bushels. The labor cost about \$5.00 for twelve acres, and it might help some other man to know my experience in saving part of a crop."

GENERAL RESULTS OF THE INJURY.

As affecting the whole Plant.—For a precise comparison of the condition of uninjured corn with that of corn attacked by the bill-bugs, 328 hills were carefully selected as representing the average condition of infested and uninfested hills in this field. One hundred and sixty-four of these were free from injury, and each of the remaining 164 contained injured stalks. There were, in all, 363 stalks in the uninjured hills and 313 in the injured hills,—a difference indicating that 50 stalks, or 14 per cent. of the whole, had been killed by the bill-bugs. In the uninjured hills 306 stalks were standing erect, 29 were leaning, and 28 had fallen to the ground. In the injured hills 64 stalks were standing, 99 were leaning, and 150 had

fallen. That is, 33 per cent. of the number of the stalks which should have been erect in the injured hills had been made to fall, and 19 per cent. of them had been weakened sufficiently to cause them to lean or bend. More generally speaking, 67 per cent. of the stalks—that is, 242 out of 363—had been either killed or noticeably injured in the infested hills.

The ratio of damage to the plant as a whole may be more simply and forcibly shown by saying that in the uninjured hills there were 306 stalks erect and in good condition, while in the injured hills there were but 64 such stalks. In other words, the bill-bugs had killed or palpably damaged 79 per cent. of the stalks in the infested hills which would have continued in good condition except for this insect attack.

As affecting the Ears.—Comparing the two lots with reference to the number and condition of the ears borne by them respectively, we find that the uninjured hills bore 349 ears of all kinds, and the injured hills 211,—a loss of 138 ears, or 40 per cent. of the whole. Of the uninjured corn 282 of the ears were graded as good, 44 as fair, 14 as poor, and 9 as nubbins, while the injured corn bore 24 good ears, 75 fair ears, 72 poor ones, and 40 nubbins.* (See Fig. 1.) Otherwise stated, besides the 40 per cent. of the ears which had been sacrificed to the bill-bugs, 9 per cent. had been considerably injured and 26 per cent. had been badly injured as a result of bill-bug attack. Not less than 75 per cent. of the ears in these hills were thus either lost or seriously injured.

The loss in number and condition of the ears borne by infested hills may perhaps be more clearly illustrated by the statement that 282 good ears were borne by the uninjured hills and only 24 by the injured,—a loss and injury combined amounting to 81 per cent.

It further appears from the data in hand that the uninjured hills bore 96 ears per hundred stalks, and the injured hills 67 ears per hundred,—a loss of thirty per cent. in number of ears per hundred stalks,—and that the uninjured corn yielded an average of 200 good or fair ears per hundred hills, and the injured corn 73 such ears per hundred hills,—a loss of 61 per cent. in number of fairly good ears.

TOTAL AMOUNT OF INJURY.

The above ratios do not hold, of course, for the entire field, but only for the part injured, and for an understanding of the condition of the field in general an estimate of the percentage of injured hills is necessary. Six hundred and eighty-two hills were examined for

*"Fair ears" were of medium size and imperfectly filled, "poor ears" were short and poorly filled, and nubbins were short, small, and not filled to the tip, and were otherwise deformed, with poor and injured grain.

this purpose, and 199, or 29 per cent., were found injured; from which we learn by a simple computation that approximately 12 per cent. of the ears which the entire field should have yielded were lost in consequence of bill-bug injury, and that 7 per cent. were badly injured and 3 per cent. considerably so.



Fig. 1. Sample Ears from Dalbey field; "good," "fair," and "poor" grades of this paper.

Samples of uninjured ears and of those called badly injured, brought in by Mr. Titus, indicate that the yield from "fair ears," "poor ears," and nubbins would not be more than one third of that from an equal number of ears of the uninjured corn. It is proper to add, consequently, to the 12 per cent. of total loss some two thirds of the 10 per cent. of injured ears, making another 6 per cent. of loss, or a total of 18 per cent. for the entire field.

This conclusion is substantially supported by the owner's estimate of twenty bushels per acre for the infested area and fifty bushels for the uninfested; since, by using the above-mentioned ratio of 29 per cent. for the number of hills injured, we find that the average yield would be 41.3 bushels per acre, a quantity loss of 8.7 bushels per acre because of bill-bug injury, or 17 per cent. of the normal yield. No account is taken in this estimate of the deterioration in quality of the injured corn, which, if included, would increase the loss materially. As the season was a favorable one for corn, and as the variety used (Reid's Yellow Dent) was reported to have hardened much earlier than other varieties planted at the same time, this loss is probably under rather than over the general average un-

der similar conditions of injury. The following table will serve to exhibit these data and conclusions in more compact form.

STATISTICS OF BILL-BUG INJURY TO CORN, DALBEY FIELD, 1902.

	Uninjured hills		Injured hills		Losses from injury	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
Number of hills..	164		164			
Number of stalks	363		313	86	50	14
Fallen stalks	28	8	150	48	122	33
Leaning stalks ..	29	8	99	27	70	19
Erect stalks.....	306		64	21	242	79
Number of ears..	349		211	60	138	40
Nubbins.....	9	3	40	12	31	9
Poor ears.....	14	4	72	21	58	17
Fair ears.....	44	13	75	22	31	9
Good ears..	282		24	9	258	81

METHODS OF PREVENTION.

The contrast observed between corn grown on timothy sod and plowed early in fall, and the Dalbey field, which was plowed only a few days before planting, was discussed in my Eleventh Report. No trace of bill-bug injury was detected on the fall-plowed land, although dead timothy bulbs still in the ground showed distinctly that they had been hollowed out by bill-bug larvæ. The inference is thus strongly suggested that early fall-plowing of timothy previous to corn planting will protect the corn from injury. A similar statement was made in 1892 by Osborn and Gossard, who say that since worse injuries are likely to occur on land in grass the preceding year or adjacent to such land, plowing should be done as early in the previous season as possible; and that since bill-bug injury is mainly done early, infested ground should be planted as late as practicable.*

John B. Smith, the State Entomologist of New Jersey, advised, in the same year, plowing of sod for corn in fall and early winter, with a view to killing out the bill-bug larvæ living in or under the sod; and in the following year he says that this injury has been minimized where fall plowing has been practiced.†

F. M. Webster also surmises ‡ that fall plowing would probably result in the diminution or prevention of the injury, and suggests planting some other crop than corn where the occurrence of this injury is very probable; and H. E. Weed says in 1895 § that where

*Bull. 18, Ia. Agr. Exper. Station, pp. 507-509.

†Twelfth and Thirteenth Ann. Reports, N. J. Agr. Exper. Station, for the years 1891 (pp. 394, 395) and 1892 (p. 390).

‡"Ohio Farmer," July 20, 1893, p. 57.

§Bull. 35, Miss. Agr. Exper. Station, p. 154.

sod has been broken up in fall the bill-bugs will do but little damage the following spring, and that the second planting, whenever the time of plowing, will be little if at all attacked.

Early fall-plowing of grass-lands would consequently seem, in the present state of our knowledge, to diminish greatly, if not completely to prevent, injury to corn by bill-bugs the following year; a statement which must be applied to blue-grass pastures as well as to timothy meadows, since the bill-bug most abundant in timothy, *Sphenophorus parvulus*, has also been found destructive in blue-grass lawns. (See Bull. 22, U. S. Dept. Agr., Div. Ent., p. 99.)

As a check to injury to timothy meadows I see nothing better than to avoid keeping the same ground in timothy for more than two years at a time. Where the pest becomes so common and destructive as in the Dalbey neighborhood, it would seem wise to substitute clover for timothy, so far as practicable, for a considerable term of years.

SUMMARY.

In a forty-acre field of corn in Christian county, injury by bill-bugs was found to have affected about 29 per cent. of the hills, diminishing the number of stalks in such hills by 14 per cent. and the number of ears by 40 per cent., and seriously injuring 26 per cent. more of the ears. It also caused about a third of the stalks in the injured hills to fall to the ground, and weakened about a fifth of them additional. The total loss in the field was estimated at 18 per cent. of the crop, or nearly nine bushels to the acre.

Comparison of this with other fields shows that the injury was due to planting corn after timothy plowed in spring, and that most of it could have been prevented by early fall-plowing of the timothy sod.

FIELD EXPERIMENTS ON THE CORN ROOT-APHIS (*APHIS MAIDIRADICIS* FORBES).

The corn root-aphis, wintering as an egg in the nests of ants in corn fields, begins to hatch, according to our observations in central Illinois, about April 8, and may continue this process for as much as six weeks, or until the latter part of May.* The earliest individuals of this first generation get their growth in approximately twenty days, and then give origin at once to representatives of the second generation, which in eighteen or nineteen days may themselves begin to reproduce. The growing period for an individual of the third generation is approximately eleven days, making a total of not far from fifty days for the entire life of a series of the first born of the first three generations from the egg. That is, by the last of May the latest to hatch of the first generation would coexist in the fields with the earliest born of the third generation. All hatching from the egg are wingless females, but a small, and no doubt variable, percentage of the second and third generations are winged, and leave their underground quarters to fly abroad and start new colonies elsewhere. The later steps of this life history are not necessary to a discussion of the experiments here reported.

In view of the fact that the young lice are dependent upon their attendant ants, at least until they have been placed upon the roots of plants suitable for their maintenance, it has seemed to me probable that an early and repeated stirring of the ground infested by these insects in early spring, scattering the eggs and young aphids again and again through the dirt, and killing the young weeds in the corn field upon which they must at first depend for food, would have the effect to destroy great numbers of them and thus to weaken the force of the aphid attack upon the young corn at a time when it is most susceptible to injury.

THE SEASON OF 1904.

With a view to testing this supposition, a field experiment was arranged in the spring of 1904, to be made in two neighborhoods notorious for some years for an abundance of the root-aphis on corn and a considerable injury to the crop in consequence. Circumstances beyond my control prevented, last year, as early a beginning as might have been desirable, and nothing was done in the experi-

*We have this year collected eggs of the corn root-aphis from ants' nests in the field May 19. These eggs hatched under our observation, and the young were maintained on corn, but were not kept until mature.

mental fields until May 13 in one locality, and May 23 in the other. I owe the opportunity to undertake the investigation at this time to Dr. J. W. Folsom, Instructor in Entomology at the University of Illinois, who was good enough to undertake the field inspections for me, and upon the report of whose observations the following statement of results is based.

The season was at least a fortnight later than usual, and it is consequently difficult to say just what generations of the aphids were in existence at the time. Judging, however, by the calendar for the three earliest generations given above, and by the field and insectary work of 1905, reported farther on, it seems likely that the first and second generations were abundant in the fields, and that the third had not yet begun to appear. That the second was present is unquestionable, since occasional winged individuals were found.

The Galesburg Cultivation Experiment. (Table I).—In the first experiment, made on the farm of Mr. J. H. Coolidge, about three miles from Galesburg, in Knox county, Ill., two parts of a large field of corn were used, one of which (Plat A) received the usual treatment in preparation for planting and the ordinary cultivation afterwards, while in the other, the experimental plat (Plat, B), the ground was repeatedly disked and harrowed between plowing and planting, and harrowed and cultivated promptly thereafter.* In this experimental plat were thirty-two rows, each eighty rods long, and in the check plat ninety rows of the same length. The latter was plowed early in May, planted May 13 to 17, harrowed once thereafter, and cultivated June 9, the condition of the corn with reference to ants and root-lice being there determined on the 10th of June. The thirty-two experimental rows were plowed May 14 to 16, the ground was thoroughly disked three times on the 18th, 21st, and 25th of May, also harrowed May 25, and planted on this same day. It was cultivated May 28, harrowed on the 30th, and inspected June 10.

It will be noticed as an important difference between these two fields that the experimental plat was planted ten days later than the

*The various operations on the ground used in these experiments were as follows:—

First, plowing with an ordinary mold-board plow; second, harrowing with a toothed harrow; third, disking with a disk harrow; fourth, spading with a so-called spading harrow; fifth, pulverizing with a so-called "Acme" harrow, sometimes known and sold as a "pulverizer;" sixth, rolling with an ordinary smooth roller; seventh, cultivating with an ordinary "sulky" cultivator with shovels. These terms are used as above defined throughout this paper in both tables and text. The plowing in the experimental plats was from five to seven inches deep; the toothed harrow stirred the earth, as a rule, to a depth of about two inches; the disk harrow commonly worked twice as deep or more, moving the dirt laterally and mixing it thoroughly in the process; the spading harrow differed but little from the disk harrow in its operation except that it was likely to go deeper, and did not move the earth laterally to so great a distance; the "Acme" harrow, or "pulverizer," consisting of a row of blades set obliquely into an angular beam, followed by a transverse row of cylindrical pointed teeth, worked to a depth of about three inches, as a rule, stirring and pulverizing the ground more effectually than the common toothed harrow, but not to the depth of the disks or moving it laterally as far.

check. This was due to rainy weather, which interrupted the planting; but as sixteen days elapsed between the planting and the inspection, there was doubtless ample opportunity for the transfer of all living root-lice from the weeds to the corn,—a conclusion to which I think no one will take exception who has been accustomed to observe the corn-field ant in charge of the corn root-aphis.

Additional to this, the difference in the treatment of the plats was the disking of the experimental plat three times and its harrowing once, and the differences between these plats with respect to ants and root-lice are to be taken as due to this additional and repeated stirring of the soil of the experimental plat.

June 10, two hundred and twenty-five hills, distributed over five different rows of the experimental (B) plat, were carefully examined by Dr. Folsom by digging up the corn and counting the ants and root-lice found upon the roots and in the hills. The rows chosen for these counts were taken from various parts of the field, being respectively the first, seventh, ninth, twentieth, and thirty-second of the entire plat. The last, it will be noticed, was the row next adjacent to the check plat. In the latter plat (A) seventy-five hills were similarly examined from the first, second, and ninetieth rows.

For convenience in comparison, the numbers given will be those for a hundred hills of corn taken as a unit. It thus appears (see Table I.) that twenty-eight per cent. of the hills of the check plat (A) were infested with ants, and that on the experimental plat ten per cent. of the hills were so infested; that seventeen per cent. of the check hills were infested by root-lice, and three per cent. of the experimental hills; that one hundred of the check hills contained 2263 ants, and one hundred of the experimental hills, 185 ants; that one hundred of the check hills contained 858 root-lice, and one hundred of the experimental hills, 79 root-lice. Or, more briefly stated, the untreated or check part of this field contained in equal areas, about twelve times as many ants and three times as many hills infested by them, and about eleven times as many root-lice and six times as many hills infested by them, as did the treated or experimental plat.

TABLE I. ABSTRACT OF COOLIDGE EXPERIMENT, 1904.

(Planted May 13-17 and May 25; examined June 10.)

	Plat A		Plat B	
	*Plowed (1), harrowed (2), cultivated (9)		*Plowed (1), disked three times (3, 4, 5), harrowed (6), cultivated (7), harrowed (8)	
	75 hills examined		225 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	28	2263	10	185
Aphids....	17	858	3	79

1. Plowed May 14 to 16. 2. Harrowed May 17. 3. Disked May 18. 4. Disked May 21.
5. Disked May 25. 6. Harrowed May 25. 7. Cultivated May 28. 8. Harrowed May 30.
9. Cultivated June 9.

The Harvel Experiment. (Table II.).—In the second experiment, made on the farm of Mr. A. T. Doerr, near Harvel, in Christian county, a field of nine acres was divided into two parts, an experimental plat of three acres (Plat B) and a check plat (A) of six acres. In this field also the experimental plat consisted of thirty-two rows eighty rods in length.

The check plat (A) received no treatment until June 1, when it was spaded and harrowed. It was planted June 2 and harrowed June 13, the inspection being made the following day. On the experimental plat the stalks were harrowed down, raked, and burned May 13, the ground was plowed May 23, harrowed May 25, "spaded" on the 26th, and harrowed again on the 28th. At this time the field was practically free from weeds. On the 29th it rained all day, the first rain since the ground was plowed. This plat was spaded and harrowed June 1 and 2, and planted on the latter day. Rain followed on the 3d day of June, and the weather was wet until the 9th. The plat was rolled and harrowed on the 11th and cross-harrowed on the 13th, the inspection following the next day. In this case it will be noticed that the whole field was planted at the same time.

The harrowing to break down the stalks could scarcely have disturbed the ground sufficiently to interfere with the operations of the ants, and in a comparison of the plats that item may best be omitted. The difference in treatment is thus reduced to once plowing, once spading, harrowing three times, and rolling once, and to this

*Figures in parentheses refer to dates given at bottom of table.

the difference of the two plats with reference to ants and root-lice can fairly be attributed.

For a comparison of these plats seventy-five hills of corn were dug up in the check plat and one hundred in the experimental plat. Reducing the numbers given, for convenience of comparison, to a unit of one hundred hills, it appears (Table II.) that sixty-two per cent. of the hills were infested with ants on the check plat, and twenty-five per cent. on the experimental plat; that forty-four per cent. of the check hills were infested by root-lice, and eleven per cent. of the experimental hills; that one hundred of the check hills contained 1961 ants, and one hundred of the experimental hills, 630 ants; that one hundred of the check hills contained 1464 root-lice, and one hundred of the experimental hills, 198 root-lice. Or, more briefly and generally stated, and comparing equal areas of the two plats, we see that the check plat contained approximately three times as many ants infesting two and a half times as many hills, and seven times as many root-lice infesting four times as many hills as did the experimental plat.

The difference in apparent effect of treatment between the Galesburg field and the Harvel field may have been due to the fact that the Harvel field was much worse infested than the other. Twenty-eight per cent. of the hills were infested with ants at Galesburg and sixty-two per cent. at Harvel; and seventeen per cent. of the hills were infested with root-lice at Galesburg and forty-four per cent. at Harvel, with a difference of only four days in the dates of inspection.

Where both ants and root-lice are numerous, the chances that some of the former will find some of the latter after both have been thoroughly scattered through the soil, is doubtless greater than where both ants and root-lice are relatively few. Of course, as fast as root-lice or their eggs are recovered by the ants, whether originally the property of the ants or not, they will be appropriated and established on the plants in the field. Furthermore, later observations reported in this paper, have made it probable that ants actively convey their charges from one part to another of the field as conditions become less favorable where they were established. It is likely, consequently, that in a crowded field the root-lice would be carried over to plants lightly infested on the experimental plat, and that the normal results of the treatment would be thus to some extent masked or lost.

It is at any rate made certain by our later observations that as the food plant becomes crowded, much larger percentages of winged lice appear, and these, by emerging from the ground and scattering abroad, tend to diminish the ratio of increase in the over-infested field and to increase it elsewhere. Such a migration of winged lice

would still further diminish and mask the effect of the treatment. In other words, if an entire field is treated, the benefit will be greater than where only an experimental plat is used, and the results of treatment here given are less than they should be if they are correctly to indicate the probable effect of the procedure used.

It should be noticed further that the treatment of the Coolidge and the Doerr fields was different especially in the fact that the latter was harrowed three times while the Coolidge field was disked three times. As the harrow tooth does not penetrate the earth to so great a depth as the disk, and does not move the dirt so far or mix it so well, much of the difference in result is probably attributable to this difference of implements.

TABLE II. ABSTRACT OF DOERR EXPERIMENT, 1904.

(Planted June 2; examined June 14.)

	Plat A		Plat B.	
	*Spaded (5), harrowed twice (6, 9)		*Plowed (1), harrowed (2), spaded (3), harrowed (4), spaded (5), harrowed (6), rolled (7), harrowed twice (8, 9)	
	75 hills examined		100 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	62	1961	25	630
Aphids.....	44	1464	11	198

1. Plowed May 23. 2. Harrowed May 25. 3. Spaded (with spading harrow) May 26.
4. Harrowed May 28. 5. Spaded June 1. 6. Harrowed June 2. 7. Rolled June 11. 8. Harrowed June 11. 9. Harrowed June 13.

THE SEASON OF 1905. BRADFORD, ILLINOIS.

For a further test of agricultural measures against the corn root-aphis, I planned and provided for a field operation to begin as early as practicable in the spring of 1905, in a neighborhood in Stark county to which my attention had been especially called by the following letter of March 11 from Messrs. Deyo and Foster, real estate agents at Bradford, Ill.

"The farmers here are troubled with lice on the roots of the corn. Even on good ground we find that the roots are alive with them and the corn makes a very poor growth until about harvest-time. If we have rains it makes a fair yield, but blows over very

*See note to Table I., p. 105.

easily. Will you please tell me what you know in regard to the matter, and what has been done on this subject."

Two assistants of the office, Mr. E. P. Taylor and Mr. E. O. G. Kelly, visited this neighborhood April 6 to 13, and after a careful survey of a large number of farms, selected three for special experiments, belonging respectively to H. B. Hinman, Edward Finnegan, and Frank Barto. Special observations were also made on the underground aphids in fields of corn and oats in comparison, on the farm of the F. H. Thompson Estate.

At the time of this first visit the root aphids were all still in the egg stage in the burrows of the small brown ant (*Lasius niger alienus*). The ants themselves were opening and extending their burrows, and the aphid eggs were found in clusters in carefully formed chambers about an inch under ground, in varying numbers, the maximum observed in a single nest being two hundred and seventy-five. The ants themselves had gone as deep as seven and a half inches, but no aphid eggs were found deeper than an inch. The fields were dry, and plowing had already begun. The soil was well pulverized, and many ants' nests had been turned over and covered up, but were not much broken up or scattered by the plow.

The first aphid egg hatched April 9, and several others from the same lot hatched the following day. The young as fast as they left the egg were placed by the ants on the roots of smartweed plants. Many of these weeds were from half an inch to an inch high, but many, barely sprouted and not yet out of the ground, had been found by the ants, and exposed by burrowing along them. The field work at this place was assigned to Mr. E. O. G. Kelly, who devoted his entire time to it for several weeks.

The weather of April and May was so unusually wet as to interfere materially with the intended treatment of the experimental plats. It also prevented as frequent access to the fields as was desirable for purposes of inspection, the exact comparison of check and experimental plats being indeed delayed until May 31, so long a time after treatment in some cases as to impair greatly the values of these comparisons. Illustrations of this point will be given in some detail in the general discussion at the conclusion of this paper. No precise record was kept of the rainfall, but the following memoranda will be of assistance in discussing the experiments.

A light rain fell April 6, but from the 10th to the 25th—the period of plowing—the weather was, on the whole, quite dry. April 27 and 28 heavy rains fell, but the fields were fairly dry again from April 30 to May 8. From the 9th to the 12th it rained hard and frequently, and the soil was continuously wet to the 15th, when it

rained heavily again, and daily thereafter to the 20th. Rains fell again on the 29th and 30th, and on the 4th of June.

The Hinman Experiment. (Table III.).—On the farm of Mr. Hinman, four and a half miles east of Bradford, was a field of seventy acres of corn, forty acres of which was selected for a field experiment. This had been planted to corn each year since 1902, and injury by the root-aphis on the higher parts of the field had been noticed in 1904.

This forty was divided, for the purposes of the experiment, into three strips. One plat (A) received the usual preparation of the land for corn. The stalks of the old corn were cut, and the ground was plowed from April 7 to 28, harrowed the first time May 3 and 4, pulverized with a disk harrow on May 5, and harrowed again May 8. Plat C was reserved for an experiment with minimum cultivation. The stalks were cut, and the ground was plowed April 7 to 28, like the preceding, and harrowed May 3 and 4 and again May 8. Plat B was set aside for an experiment with the effects of maximum cultivation, but repeated rains greatly hindered the farmer's work, and finally, as a consequence, this field was plowed like the others April 7 to 28, after the cutting of the stalks, was harrowed May 3 and 4, disked May 5 and again May 8, and harrowed also on the latter date. The preparation of these three plats thus varied as follows:—

Plat C (minimum cultivation) differed from plat A, the check, only in the fact that the ground was not disked. Plat B (maximum), on the other hand, differed from the check only in the fact that it was disked a second time. B thus differed from C by two additional treatments with the disk harrow. It will be noticed that all the plats were treated alike until May 5, when the ground of two of the plats was first disked, and that A and B received identical treatment until May 8, when the latter was disked a second time.

The entire field was planted on three different dates, the planted rows running crosswise of the plats. The first hundred rows on the north end of each plat were planted May 8, and, rains intervening, one hundred and sixty-four rows next south of these were planted May 13 and 15. Rains again followed, so packing the soil that the remainder of the field—one hundred and eight rows—was harrowed again (with an Acme harrow, sometimes called a pulverizer) and planted on the 22d and 23d of May. This last-planted section thus constituted a distinct division of the three foregoing plats, receiving one additional treatment with the Acme harrow, and being planted two weeks later than the first planting of a hundred rows and about a week later than the second planting of one hundred and sixty-four

rows. The extremes of treatment in this field, it will be seen, were between the part of plat C first planted and the part of plat B planted last, these two plats differing in the fact that the late-planted part of plat B was harrowed twice more (once with Acme and once with toothed harrow) and disked once more than the early-planted part of C.

Observations were made in the Hinman field by Mr. Kelly, at as frequent intervals as the weather permitted, during the period from May 2 until the planting was finished on the 23d. On May 2, where the ground had been merely plowed many young root-lice were seen in the field, which the ants were placing on young smartweeds. Five ants' nests, all within a space twenty feet square, were explored and found to contain from thirty to one hundred and thirty-five ants, from twenty to forty aphis eggs—green and about to hatch—and from thirty-five to eighty-six young root-lice, all of the first generation from the egg. The harrowing of the whole field May 3 and 4 stirred the weeds about and disturbed the ants and aphids, but seemed to kill neither insects nor weeds. The disk harrow or pulverizer loosened the soil to the full depth of the plowing, and scattered the ants and aphids greatly. On the 6th of May ants were everywhere on and through the soil, and an occasional aphis was seen on roots of grass or smartweed, seldom, however, with any ants in company. May 13, the ants were generally reestablished in the plowed part of the field, and many root-lice were collected from their burrows feeding on foxtail-grass and on an occasional volunteer plant of corn. 'Thirty-two ants' nests were dug out on this date, each containing from six to one hundred ants. In seventeen nests there were no root-lice, and in the remaining fifteen these varied in number from two to sixty-five. There were, on an average, twenty aphids to each nest containing them, all wingless, but many already full grown, and all apparently of the first generation from the egg. May 18, the corn planted May 8 was beginning to come up, and twenty-five hills were dug out. Ants were found in two; root-lice in none.

May 31, a test examination of this field was made by digging up in the earliest-planted portions of plats A, B, and C, fifty hills from each, and in the later-planted portions twenty-five hills from each plat. Although the number of hills dug up was perhaps too small to give satisfactory averages applicable to the entire field, Mr. Kelly tells me that the several lots were not taken entirely at random, but that each was carefully chosen with the idea of making it a fair and sufficient sample of its plat. In digging up the plants the whole root system was exposed, and all the ants and all the root-

lice were collected and counted for each hill. For convenience in comparison the data will be given in each instance for a hundred hills of corn taken as a unit. Those for the early and late plantings will be given separately—first those for the parts of the field which received the least treatment, and then, by successive steps, for those which were treated most. (See Table III.)

TABLE III. ABSTRACT OF HINMAN EXPERIMENT, 1905.

(Planted May 8, and May 13 to 15; examined May 31.)

	Plat A, 1		Plat B, 1		Plat C, 1	
	*Plowed (1), harrowed (2), disked (3), harrowed (4)		Plowed (1), harrowed (2), disked twice (3, 5), harrowed (4)		Plowed (1), harrowed twice (2, 4)	
	50 hills examined		50 hills examined		50 hills examined	
	Per cent. of hills infested	Number of insects per hun- dred hills	Per cent. of hills infested	Number of insects per hun- dred hills	Per cent. of hills infested	Number of insects per hun- dred hills
Ants.....	54	2012	26	744	64	2096
Aphids.....	40	838	12	158	48	974
	A, 2. Pulverized (6)		B, 2. Pulverized (6)		C, 2. Pulverized (6)	
	25 hills examined		25 hills examined		25 hills examined	
Ants..	24	260	12	66	24	194
Aphids.....	12	62	0	0	20	146

1. Plowed April 7 to 28. 2. Harrowed May 3 and 4. 3. Disked May 5. 4. Harrowed May 8. 5. Disked May 8. 6. Pulverized (Acme harrow) May 22 and 23.

In plat C, with minimum treatment, sixty-four per cent. of the hills were infested with ants; in plat A, with medium treatment, fifty-four per cent. were so infested; and in plat B, with maximum treatment, the percentage of infestation by ants was twenty-six. Forty-eight per cent. of the hills of plat C were infested by root-lice; forty per cent. in plat A; and twelve per cent. in plat B. One hundred hills in plat C contained 2096 ants; in A, 2012; and in B, 744. One hundred hills in C contained 974 root-lice; in A, 838; and in B, 158. In other words, taking the infestation of plat C as a basis of comparison, we find that the single additional disking of plat A reduced the number of *hills infested* by ants to eighty-four per cent., and those infested by root-lice to eighty-three

*See note to Table I., p. 105.

per cent., the number of *ants* per hundred hills to ninety-five per cent., and the number of *root-lice* per hundred hills to eighty-six per cent. Comparing similarly plat B with plat C, we find that the effect of disking twice was to reduce the number of hills of corn infested by ants to forty-one per cent., and the number infested by root-lice to twenty-five per cent., and also to reduce the number of ants per hundred hills of corn to thirty-five per cent., and the number of root-lice per hundred hills to sixteen per cent. Still more briefly stated, the root-louse infestation was reduced approximately fifteen per cent. by disking once; and seventy-five per cent. as to the number of hills infested, or eighty-four per cent. as to the number of root-lice in the field, by disking twice (see experiment 5, Table V.).

A comparison of the early-planted part of section C, in which fifty hills were examined, with the late-planted part of section B, in which twenty-five hills were examined, gives a surprising contrast. It will be remembered that all the latest-planted sections received an additional pulverizing just before planting,—necessitated, in the owner's judgment, by the packing effect of a heavy rain while the planting of the field was in progress. If this circumstance be taken into account, then it may be said that a comparison of these two areas indicates that three times disking—the last time soon after a heavy packing rain—may reduce the number of hills infested by ants to nineteen per cent., and the number of ants themselves to three per cent., and may obliterate the root-lice entirely, since none were found in the twenty-five hills searched in the late-planted part of section B.

The effect of a single disking, following closely upon a beating rain, as shown by counts made in each of the three sections before and after these events and by averaging the percentages for the three plats, is as follows: The hills infested by ants were reduced to forty-three per cent. and the ants themselves to ten per cent. of the number to be found in those parts of the field which had not been disked after the rain, while the root-lice were reduced by the same treatment, to thirty-six per cent. in the number of hills infested and to eleven per cent. in the number of insects in the field.

A further instructive conclusion may be derived from the observations of May 31 by comparing the product of fifty badly infested hills with the remaining 225 dug up on that day. The total number of root-lice found in the fifty hills was 5254, averaging over 105 per hill, while the total in the 225 hills was 1068, or an average of five per hill. If these two collections of root-lice be compared with reference to the percentage of the adults which have developed wings, added to the pupæ, which would acquire them at the next

molt, we find that this ratio of winged forms is much greater in the badly infested hills; that the ratio of winged specimens increases, in other words, with the crowding of the insects and the consequent pressure on their food supply. In the 225 slightly infested hills were 225 wingless adults and 54 winged adults and pupæ, a ratio of 21 per cent.; while in the fifty badly infested hills were 227 wingless adults and 349 winged adults and pupæ, a ratio of 64 per cent. of the winged form. That is, the winged insects were three times as numerous in the crowded colonies as they were in the smaller ones. It is quite probable that experiment will show that this increase of the ratio of winged to wingless specimens might be brought about experimentally by various means which have the effect to diminish the average food supply. It is to be expected, consequently, that mere drouth, if it goes to the extreme of injuring the plant infested, may have the effect to break the force of the root-louse attack by stimulating the development of winged specimens, which, leaving the earth and flying abroad, would give the infested plant a chance to rally against injury.

The Finnegan Experiment. (Table IV.).—On the farm of Edward Finnegan, one and a half miles northeast of Bradford, a field of eighteen acres was selected for experiment. This field had been planted to corn in 1904, to oats in 1903, and to corn for the three preceding years. A considerable injury, apparently due to the corn root-aphis, had been noticed in it in 1904. Two parts of this field, which may be called plats A and B, were treated as follows:—

Both were plowed April 18 to 21, disked May 22, harrowed May 23 and 24, and planted May 24. B differed from A only in the fact that it was twice disked in succession May 22, instead of once only on that date. Plat B was a strip running lengthwise of the field from north to south, and twenty-two rows wide, beginning on the west side; and plat A comprised the greater part of the field, extending eighty-eight rows inward from the eastern border. Smartweed and grass grew two or three inches high by May 22, heavy rains having by this time packed the soil very closely. The corn was put in about three inches deep, and began to show above the surface by May 30, on which date the first root-aphis was found in a hill of corn infested by *Lasius alienus*. These fields were examined June 9 for a test of the results of the single additional treatment with the disk harrow in which alone the two plats differed (see Table IV.). Fifty hills were examined from each plat, with the general result that in the check plat, A, seventy-five per cent. of them were infested by ants, and that in the experimental plat, B, fifty per cent. of them were so infested. In the check plat, A,

seventy-four per cent. of the hills were infested by root-lice, and forty-four per cent. in the experimental plat. The former contained 3034 ants per hundred hills, and the latter 1746—fifty-seven per cent. of the first number. The latter, or check plat, also contained 2392 root-lice per hundred hills, and the former, or experimental plat, 1362 root-lice per hundred hills—sixty per cent. of the number in the first.

More briefly stated, the single treatment with the disk harrow May 22, following immediately upon an earlier treatment the same day (see Experiment 4, Table V.), had reduced the infestation by ants by forty-two per cent. in number of insects and by thirty-three per cent. in number of hills infested; and had reduced the infestation by root-lice by forty-three per cent. in number of insects and by forty-one per cent. in number of hills infested, the result being tested by a critical examination made sixteen days after the field was planted. In short, a single disking of the soil had diminished the infestation by ants and root-lice generally by something over one third.

TABLE IV. ABSTRACT OF FINNEGAN EXPERIMENT. 1905.

(Planted May 24; examined June 9.)

	Plat A		Plat B	
	*Plowed (1), disked (2), harrowed (4)		Plowed (1), disked twice (2, 3), harrowed (4)	
	50 hills examined		50 hills examined	
	Per cent. of hills infested	Number of insects per hundred hills	Per cent. of hills infested	Number of insects per hundred hills
Ants.....	75	3034	50	1746
Aphids.....	74	2392	44	1362

1. Plowed April 18 to 21. 2. Disked first time May 22. 3. Disked second time May 22.
4. Harrowed May 23 and 24.

Observations on the Barto Farm.—A field of seventy acres, forty-five in oats and the remainder in corn, on the farm of Mr. Frank Barto, near Bradford, Ill., was selected for observation because of the extraordinary abundance of ants' nests containing aphid eggs to be found in various parts of it, and because of the history of the oats fields with reference to corn preceding, and of one of the corn fields with reference to oats. It was the principal object of the observations here made, to ascertain the effect on the corn to it-aphis of a change of crop from corn to oats.

*See note to Table I., p. 105.

For the purposes of this discussion the field may be divided into two parts: one of twenty acres of corn which had been in that crop continuously for at least three years preceding—five acres indeed having been in corn since 1899: and the other of forty-five acres of oats, thirty-five acres of which had been in corn for three years preceding, and ten acres continuously in that crop since 1899 until sowed to oats the present spring.

April 27 several nests of *Lasius alienus* were explored, each containing numerous root-louse eggs and some root-lice. Above and immediately about the ants' nests the smartweed was withering and the roots were drained of sap, and in many cases blackened and decayed. The tunnels of the ants extended sometimes as far as a foot and a half from the main entrance, and ranged irregularly from a depth of an inch to about six inches. The root-lice were mainly on smartweed (*Polygonum*) roots, from sixteen to twenty on a single plant. In that part of the field which had been six years in corn and was to be planted to the same crop again this year, eighteen nests were found within a distance of two hundred hills; and in that part which had been in corn for the three preceding years, thirty nests were found between two rows three hundred and fifty hills in length. Twelve of the nests were explored in these parts of the field, five in the first mentioned and seven in the second. The ants in these colonies ranged in number from eighteen to one hundred and twenty-six, averaging fifty-seven each. Four of them contained from one hundred to three hundred larvæ and eggs of ants. All were plentifully stocked with the eggs and young of root-lice, whether in all cases, or even in the majority, those of *Aphis maidi-radici* (the corn root-aphis) it was impossible to say with certainty at that early date. Root-louse eggs varied in number from seventy-five to two hundred and seventy-five per nest, averaging one hundred and sixty-one, and young root-lice were found in numbers varying from two to seventy-eight, with an average of thirty-five, a total average of one hundred and ninety-six root-louse eggs and young to each ant's nest.

May 1, root-lice nearly full grown, together with many young, were taken from roots of smartweed and ragweed (*Ambrosia*) in that part of the field sown to oats this spring but in corn for three year preceding. Two hundred oats plants were examined on and near the nests of ants containing root-lice, but not a louse was found upon them. Here again smartweeds near the nests of ants were withered and the roots were dead or actually gone. Cavities and gangways had been made by the ants beside the roots of these weeds. The first root-louse of the second generation was seen in the field

May 3, although the eggs of the preceding year were not yet all hatched.

At this time an interesting and important comparison was made between the contents of ants' nests in fields of corn last year and those on which a single crop of oats had been raised. Every nest of the former contained numerous root-lice or their eggs, while thirteen nests of *Lasius alienus* found in the oats field in corn for the three preceding years were carefully explored, but not an aphid could be found in the possession of the ants. Later, a single colony of thirty six ants was found with no eggs but with seventy-eight root-lice in their possession. These had very likely been carried in from an adjacent part of the field. In the absence of root-lice the ants seemed to be maintaining themselves, in part at least, by capturing beetles and insect larvæ, the remains of which were found in their nests.

On the other hand, in the oats fields which had been in corn for some years before, ants were now less abundant than in the adjacent corn, and the eggs and young of root-lice were common in their nests. In fourteen nests explored May 3, eight hundred and eighty-six ants were found, an average of sixty-three per nest, together with five hundred and sixty-five eggs and eight hundred and eighty-two young of root-lice. This was an average of ninety-eight to each nest, and is to be compared with the average of one hundred and ninety-six root-lice and root-lice eggs per nest in the adjacent fields of corn.

By May 8 the second generation of the root-lice was abundant in the oats fields, but none of them had as yet acquired wings. Heavy rains fell on the 10th and 11th of May and at occasional intervals thereafter, and the muddy fields were not revisited until May 18. Then many ants were crawling about and making new burrows in the ground (each of which contained from two to ten ants, and no root-lice. Specimens of the latter, dropped near these new-made burrows, were promptly pounced upon by ants and carried under ground. The root-lice seemed to be less numerous than before, as if affected by the rains. On the 22d of May the fields continuously in corn were visited again, and fourteen nests of ants were dug out and the contents caught and counted. Five hundred and seventy-one ants were found in these nests, an average of forty-one each, and six hundred and fifty-five ant larvæ in eight of them. The aphid contents, on the other hand, had dwindled greatly, consisting of forty-six wingless adults, thirty-three pupæ, and one hundred and seventy-three young, a total average of thirty-seven to each ant's nest.

May 30 the oats fields were revisited by Mr. Kelly, in company with Mr. C. A. Hart, whom I had sent out from the office to inspect the situation, and to the astonishment of both not an ant nor an aphid could be found in the whole forty-five acres of this crop. As recent rains had fallen, it was at first surmised that the ants' burrows had merely been obliterated, but protracted search on the two following days, which were warm and bright, gave the same negative result. The smartweeds were now virtually all dead, and the oats were tall enough to shade the ground. The entire ant and aphid population of these fields had evidently abandoned them, and could not be traced.

June 22 another visit was made to this field, and prolonged search again failed to discover a single insect of either kind, although in the adjoining corn both ants and aphids were numerous, and in one of the fields, where nearly every hill was infested, considerable injury was being done. The field of corn which had been in oats the preceding year, and in which on previous visits ants were found but not a root-louse, was now badly infested, and this fact offered the only possible hint of the whereabouts of the insects which had left the oats the preceding month.

Observations in the Thompson Field.—For further evidence concerning the effects of a change from corn to oats, observations were made by Mr. Kelly on two adjacent fields of forty acres each, one in corn this spring and the other in oats, both fields having been in corn continuously for the three years preceding, and both being heavily infested by *Aphis maidiradicis* May 8, when first selected for this comparison.

May 19, the ground being very wet after a recent rain, eight ant hills were examined in the oats field and their contents collected. Three hundred and thirty-four ants were obtained, an average of forty-two to each colony, and one hundred and sixty-seven aphids, an average of twenty-one to each ant's nest. Fifty of these aphids were wingless adults and eight were pupæ, the remainder, of course, being young in various stages. These were contained in seven of the nests, one nest being without root-lice. The number varied from two to forty-six to a nest.

The other field had been plowed for corn April 28 to May 5, and harrowed twice. Hard rains following, it was disked twice May 19 and 20, and harrowed again just as it was planted. Both ants and root-lice were found in this corn May 20, but no record was made of their number or distribution until June 2, at which time a final visit was made for a comparison of the two fields.

In the oats not an ant nor an aphid could now be found; even the borders of the field nearest the corn had been completely aban-

done by both. In the corn, from a hundred hills chosen as fairly representative of the whole field 2156 ants were taken, an average of twenty-two to the hill, fifty-two of the hundred hills being infested by them. In the same hills 1507 root-lice were found, an average of fifteen to the hill, forty-three of the hills being infested. Each ant's nest contained on an average forty-one ants and thirty-five root-lice,—less than one root-louse to each ant. The winged lice in these hundred hills averaged in number twenty-seven per cent. of all the adults. Collections made on higher and drier parts of the field were compared with those from lower and wetter portions, but gave no marked difference in respect either to the ants or aphids, or to the ratios of winged to wingless adults.

Observations made in this field correspond precisely, it will be seen, to those reported from the Barto fields with reference to the total disappearance, late in May, of ants and aphids from oats grown on old corn ground.

ADDITIONAL MISCELLANEOUS OBSERVATIONS.

April 11, at Bradford, an ant's nest was explored, the burrows of which extended throughout an area approximately three by four feet, and to depths varying from one to four inches. Ants were distributed everywhere through the soil within these dimensions, but all the aphid eggs seen were collected at one place.

April 12, a nest of *Lasius alienus*, around which a few young smartweeds (*Polygonum persicaria*) about one inch high were scattered, was watched by Mr. Kelly for two hours and a half. An ant coming up with a young root-louse in its mandibles carried this about two feet and placed it on a smartweed very near the ground, and the root-louse, after crawling about half an inch, thrust its beak into the plant. Six more ants transferred a single root-louse each to smartweeds above ground within the next twenty minutes. In about an hour and a half one of the ants returned its root-louse to the nest, and thirty-five minutes later all had been carried back. One of these ants, which was so marked that it could be recognized on its return, recovered and carried to the nest the same root-louse which it had previously brought out.

Another nest of the ants was carefully explored on the 13th. The burrows were found to vary in diameter from one sixteenth to three eighths of an inch, and to range from one to six inches below the surface. In a cell a quarter of an inch in diameter were many eggs and a few young of the corn root-aphid. When these were disturbed the ants seized them and retreated to more distant parts of

their habitation. About two inches from this collection of eggs a smartweed root had been exposed by the ants under ground, and on this about fifteen of the root-lice were feeding.

In another nest explored on the same day the burrows were from one tenth to one eighth of an inch in diameter. Under a space of two square feet four clusters of root-louse eggs and some recently hatched aphids were found. Six young aphids on the roots of a smartweed in one of these burrows were promptly seized by the ants and carried farther into their retreat. At four o'clock p. m. most of the ants had retired for the day, but two brought out an aphid each, taking it back, however, in less than two minutes. Twenty-two ants were found in this nest, together with a bunch of aphid eggs about as large as a pea. Two inches from this mass of eggs was a sprouting smartweed that had not yet broken ground, and on it were a number of young root-lice. When exposed by digging, the ants immediately seized them and carried them away. Roots of smartweed, grasses, and ragweed exposed in burrows, sometimes had no root-lice on them, although in one case a root-louse was found on a ragweed root.

May 5 ten nearly grown aphids were taken from a smartweed root and placed on the bare ground. They crawled actively about and two of them entered a crack in the earth as if to escape the light. One of these was found by an ant which carried it away. Two small ones crawled about four feet and stopped as if exhausted, but two larger aphids traveled more than ten feet in an hour and twenty minutes. All these aphids were seemingly averse to the light, and crawled away from the sun.

May 8 several young of the second brood were found. Three full-grown stem-mothers were unearthed, near one of which were four young, and near another, two. The third was in the act of giving birth to an aphid, of which an ant took possession as soon as it was born and carried it to a new plant. Presently all the other young were carried away by ants and placed on plant roots. A second aphid was born from the same mother within forty minutes after the first. This also was soon carried away and placed on a fresh plant.

On the 9th, which was cool and damp, a heavy rain having fallen during the morning, the ants were seen taking the root-lice from the old smartweed roots—which were now dead and dry or even decayed—and placing them on the roots of younger plants.

On May 12 Mr. Kelly took a corn root-aphid from a plant and placed it on the ground. A root-louse ant (*Lasius alienus*) found it presently, carried it away to a distance of four feet, placed it on the

ground, made a burrow to the root of a plant of foxtail-grass (*Setaria*) and put the root-louse on the plant, where it was afterwards found by digging. Presently she took the root-louse away again to a new place, and finding a root of foxtail exposed in a crack of the earth she placed the aphid on it, and there the insect remained until the observation closed.

April 23 a *Harpalus caliginosus* was found in an ant's (*Lasius alienus*) nest, where it was surrounded by several fragments of ants which it had evidently been eating. April 26 another harpalid was captured under a board, where it was eating ants and was surrounded by fragments of those already devoured.

April 29 the remains of four seed-corn beetles (*Agonodcrus pallipes*) were seen in an ant's nest which contained about two hundred ants, but no root-lice. May 15 a *Lasius alienus* was found feeding on an earthworm.

Systematic breeding-cage experiments, made in my insectary at Urbana with eggs and aphids sent in by Mr. Kelly, gave results substantially consistent with those previously published* as to periods and succession of generations, but yielded a much larger number of young for each mother aphid than I have previously reared. The largest number hitherto reported was fifteen young, and the average reared was much less than that. This year, however, thirty-six adults bred between July 1 and September 14 produced from twenty to eighty-four young each, with an average of forty-one to each parent, and this may probably be accepted as the known rate of multiplication under favorable conditions. The period of development from birth to reproductive maturity, as shown by the birth of the first young, varied from seven to ten days for twenty-three specimens, the average being 8.4 days. The time from the appearance of the first young of any parent to the birth of the last young of the same parent varied, in thirty-six cases, from 6 to 20 days, with an average of 10 days, and this may be taken as the ordinary length of the reproductive period in midsummer under insectary conditions.

GENERAL DISCUSSION OF THE RESULTS (TABLE V.).

The most pronounced effect of an early treatment of the soil for the control of the corn root-aphid was produced on the Coolidge farm in 1904, where disking three times and harrowing once reduced the number of hills infested by ants by sixty-four per cent., and those infested with aphids by eighty-two per cent., and the number of insects, both ants and aphids, by ninety-two per cent. each.

*Eighteenth Rep. State Ent. Ill., pp. 63-64.

In this case the field was disked on the 18th, 21st, and 25th of May, harrowed on the latter date, and examined June 9, fifteen days after the last treatment.

More remarkable, on the whole, was the effect of once harrowing with an Acme harrow May 22 and 23, after numerous heavy rains from the 15th to the 20th of May, 1905. Here a single treatment (Experiment 3, Table V.) with the disk harrow, used as soon as the ground was dry enough to work properly, reduced the number of hills infested by ants and aphids by fifty-eight per cent. and sixty-four per cent. respectively, and the number of insects in the field by ninety per cent. for the ants and eighty-nine per cent. for the aphids.

The least effective treatment, according to Mr. Kelly's notes, was a single disking, May 5, of plat A1 on the Hinman farm (Table III.), which, as shown by a comparison with C 1 of the same table, seems to have reduced the number of hills infested by only sixteen per cent. for the ants and seventeen per cent. for the aphids, and the number of insects by four per cent. for the former and fourteen per cent. for the latter. As these plats were not examined until May 31, that is to say twenty-six days after the treatment, these figures probably ought not to be taken into account. It was hardly to be expected that the original difference between check and experimental plats should continue unchanged during this interval of nearly four weeks.

Five of the pairs of plats brought into comparison differed in respect to treatment only by the fact that the experimental plat was in each case treated with a disk harrow once more than its corresponding check. If the ratios for these five plats be averaged, it appears that the result of a single disking in 1905 on the Hinman and Finnegan places may be described in general terms as reducing the number of hills infested by forty-four per cent. for the ants and fifty-one per cent. for the aphids, and the number of insects by fifty-seven per cent. for the ants and sixty-three per cent. for the aphids. Or, still more generally speaking, it may be said that the average effect of a single treatment with the disk harrow was to reduce the number of infested hills by a little less than half, and the number of insects in the field by about two thirds. If, in view of the doubtful character of one of these comparisons above mentioned, in which nearly four weeks intervened between the experimental operation and the inspection of the plats, we omit this case from our calculation, this statement may be revised to the effect that a single disking may be expected to reduce the number of infested hills by something more than half, and the number of insects in the field by nearly three fourths.

The effect of twice disking, as shown by a comparison of C 1 and B 1 of the Hinman field (Table III.) was to reduce the number of infested hills by fifty-nine per cent. for the ants and seventy-five per cent. for the aphids, and the number of insects by sixty-five per cent. and eighty-four per cent. respectively. As these two treatments were given, however, on the 5th and 8th of May, and the inspection was not until twenty-three days later, it is probable that the full effect of this treatment does not appear in this statement of the result, since there was ample time for the treated plats to become restocked by both ants and aphids by multiplication and migration and by the establishment of new aphid colonies from winged parents developed during this interval.

The general conclusion to be drawn from this whole series of experiments is to the effect that the number of both ants and aphids may be readily controlled and the injuries to corn in great measure prevented by thorough and frequent stirring of the ground previous to corn planting, and that the disk harrow or its equivalent is much the best implement for the purpose. Indeed, the treatment most effective for the destruction of the root-aphid and its attendant ant in spring is in great measure that which will be found most useful as a thorough preparation of the soil for corn, the main difference being that a thorough overturning and stirring of the soil is the essential thing for the destruction of the root-louse, while it is sufficient for the corn plant if the earth be merely pulverized in place.

If the corn farmer will prepare his old corn ground early and thoroughly, using the plow and the disk harrow by preference, he should have little trouble in the beginning of the season from the corn root-aphid, and so far as the general community acts in accordance with this idea, to that extent will later injuries by this aphid be forestalled. It is in this as in many other cases, one acting by himself alone can accomplish relatively little even for his own protection; the welfare of each depends on intelligent cooperation by all.

It is further to be concluded from the observations here reported, that if infested corn ground be planted to oats, the root-lice will leave it or perish in it (just which we do not yet know) by the end of May. A rotation with a short period in corn must consequently act to check the multiplication of this insect and to diminish its injuries to corn.

TABLE V. COMPARATIVE EXHIBIT OF RESULTS OF TREATMENT.

Experiment	Differential Treatment	Percentages of Reduction			
		Ants		Aphids	
		Hills in- fested	Number of insects	Hills in- fested	Number of insects
1. Coolidge.....	Disked three times, harrowed once..	64	92	82	92
2. Doerr	Plowed once, harrowed three times. Spaded once, rolled once.....	60	68	75	81
3. Hinman.....	Disked once, (after heavy rains)....	59	90	64	89
	Disked once, (after harrowing).....	52	63	72	81
4. Finnegan.....	Disked once, (after previous disking)	33	42	41	43
5. Hinman	Disked twice.....	59	65	75	84

FIELD EXPERIMENTS FOR THE PROTECTION OF CORN AGAINST CHINCH-BUG INJURY.

BARRIER EXPERIMENTS.

Experiment of 1895.—In my ninth entomological report, published in 1898, I gave an account, in an article on "Midsummer Measures against the Chinch-bug,"* of a field experiment made in

*Twentieth Rep. State Ent. Ill., pp. 37-44.

1895 for the destruction of that insect as it passes in June and early July from small grain to corn. The measures used in this experiment were a combination program of a dusty furrow for the arrest and destruction of chinch-bugs in dry weather, a coal-tar line with post-hole traps for use when the ground is too wet to pulverize, and kerosene emulsion for the destruction of the insect on the corn itself.

This operation, carried on in Effingham county from June 5 to 15 by one of my assistants, was highly successful in the protection of corn growing adjacent to a heavily infested 20-acre field of wheat, approximately twelve bushels of chinch-bugs being destroyed in the process at a cost of less than five dollars for the materials used.

Extreme conditions prevailed at the time of this experiment. Injury by chinch-bugs to grass, small grains, and corn had continued in this locality for some years with increasing intensity, and these insects had become so numerous in the wheat that they had already destroyed the crop and virtually all other grass-like vegetation in the field referred to, by the 5th of June. Compelled to leave the wheat to avoid starvation, they moved out of it rapidly, wholly deserting it within a very few days. The corn adjacent was thus exposed to immediate and complete destruction by the invading horde, and would inevitably have been soon destroyed if active measures had not been taken to protect it, a fact made perfectly apparent by the fate of other similarly situated fields in the neighborhood.

The weather of the season had been very dry, and it was intensely hot, conditions which, although unfavorable to the infested crops, were unusually favorable to the easy success of measures for the destruction of the chinch-bugs. A dusty furrow, readily made and maintained between the wheat and the corn, trapped the insects in myriads as they attempted to pass from one field to the other, and the heat of the dry dust in the bottom of the furrow,

fully exposed to the sun, speedily killed them. The coal-tar barrier was, in fact, required but once, and the kerosene emulsion was used only to destroy the bugs which had entered the field before the experiment began and a few which escaped into it in an interval between a shower of rain and the establishment of the tar line. As the protected field of corn bore a good crop while other fields in the neighborhood were almost wholly destroyed, the demonstration of the usefulness of this method was complete for these extreme conditions.

Experiments of 1904.—Wishing to know, however, what might be done by similar operations under more ordinary circumstances, especially when a chinch-bug outbreak was but just beginning and when the weather was generally unfavorable to success, I prepared in the spring of 1904 for several field trials, to be made at different places in southern Illinois where a previous inspection had shown that the chinch-bugs were present in numbers sufficient to threaten more or less injury to wheat and corn. The fields selected were in four localities: near Carbondale, in Jackson county; near Dubois, in Washington county; and near Fairman and Odin respectively, in Marion county.

The experiment was placed in charge of Mr. E. P. Taylor, and I owe the results here reported to his energy and faithfulness in the field, and to the fulness and exactness of his notes.

Although the prospect of insect injury was considerable at all these places in the early part of the year, the weather of the spring and early summer was so wet and much of the time so cool that the multiplication of the insects was in great measure prevented, and they finally became abundant enough to injure corn seriously only in the Carbondale neighborhood. The whole experiment was faithfully carried through, however, at all the above places, and with useful results at each.

At Carbondale, rain fell twelve times and on eleven different days between June 24 and July 25, and the ground was kept so moist by rains at all the places mentioned that the dusty furrow could not be long maintained at any of them. As a consequence, the tar line, with post-hole traps, was used throughout, and kerosene emulsion was only occasionally applied, as found necessary.

The tar lines laid at these various places aggregated more than a mile and a half in length (508 rods, exactly), and were maintained for periods varying from eleven to twenty-eight days, the total of this procedure being equivalent to the maintenance of an effective coal-tar barrier a mile in length for twenty-seven days. Post-holes were dug from one to two feet deep at a usual distance of

twenty feet apart along all these lines; and besides the continuous coal-tar strip, diagonal leaders about a foot in length were laid from each hole outwards in two directions, as shown in the accompanying diagram (Fig. 2, p. 131).

SUMMARY OF CONCLUSIONS.

As a general outcome of the work at these various places, it was demonstrated that an effective barrier against the movement of chinch-bugs may be maintained for four weeks with coal-tar, poured along a strip of ground properly prepared, at a cost for materials of seven cents a rod, or \$22.40 a mile, and that virtually all the bugs approaching these lines may be trapped and killed in post-holes properly placed for the purpose.

The time for which this barrier must be kept intact will vary from ten days, the period found necessary in the very dry weather of 1896, to thirty days, as required this year. The labor necessitated is that of raising a ridge by plowing a back furrow between the infested field and the one to be protected, smoothing and packing this strip with a light roller or by hand, digging a row of post-holes at intervals of about twenty feet, and laying the lines of tar by pouring it upon the ground from a can with a tubular spout. This line was renewed whenever it became dry or hard in the sun, or when it was covered with dust in windy weather or washed away or covered with mud by rains. It was necessary to pour fresh tar along the line from one to three times a day, the average at all places for the month being three renewals every two days.

USE OF KEROSENE EMULSION.

Where chinch-bugs had entered corn before the experiment was begun, and where, through accident or mismanagement, they escaped across the barrier, they were effectively treated with a four per cent. kerosene emulsion. It was shown that a mixture sufficiently complete and lasting for the purpose could easily be made by stirring the kerosene and the soap solution together with a stick or paddle, and that this emulsion could be conveniently applied by sprinkling or throwing it on the infested plants with a whisk-broom, or even with the bare hand. Thus prepared and used, the four per cent. emulsion was as strong as the corn would stand without some injury, and was sufficient to kill all the chinch-bugs which it touched.

The only notable failure of this method to destroy the chinch-bugs against which it was used, occurred where the infestation of

the wheat field was slight, and where so many grass-like weeds had sprung up in the wheat that they afforded food to the bugs in the field at harvest sufficient to detain them there for several days. There was virtually no migration on foot out of this field, the chinch-bugs generally lingering until the appearance of their wings enabled them to scatter by flight to more favorable breeding grounds.

At Carbondale, where they were the most abundant, the corn adjacent to infested wheat was saved from all injury worth noticing, while the crop on some other fields in that region not protected, was completely destroyed for many rods inward from the edge of the field, and badly injured for a considerable distance further.

The Carbondale Experiment.—On a farm situated one mile west of Carbondale, belonging to Mr. Robert Thorpe and referred to in this account as the Thorpe farm, was an irregularly shaped field of one hundred and forty acres of wheat which in June, 1904, was generally and considerably infested by chinch-bugs, sufficiently so to threaten notable injury to the wheat crop itself and the destruction at harvest-time of much of the corn adjacent. Indeed, by the last week in June the wheat was ripening irregularly, turning brown in patches where the chinch-bug was most abundant, in advance of the general ripening of the field, and from these patches the insects were already beginning to move into other crops.

A corn field of twenty-seven acres cornered into this wheat at the northwest in such a way that the division line of the two crops measured three hundred and seventeen yards on the east and three hundred and thirty-eight yards on the south, the remainder of the southern side being bounded by woodland. In the southwest corner of this wheat was another field of corn of only four acres, so placed that it was bounded by infested wheat only on one side for about one hundred yards. A third field of corn, on an adjacent farm belonging to Ralph Thompson, was also exposed to invasion from the wheat field for a distance of about one hundred and forty yards. This corn was south of the wheat, from which it was separated by a roadway of the usual width.

The situation here was complicated by the fact that in the northwest field of twenty-seven acres of corn a large pile of waste from a corn shredder had been left the preceding fall, in which quantities of chinch-bugs had passed the winter. Coming out in spring, many of these laid their eggs in the young corn, which thus became immediately infested from within by the first generation of the year. A part of the wheat bordering this field on the south had ripened early, owing perhaps to chinch-bug injury, and the bugs from this vicinity had already begun to invade the corn before our experiment

was begun, infesting a strip about thirty yards in length and seven or eight rows deep.

To prevent the further entrance of chinch-bugs into these three corn fields from without, 1080 yards (about three fifths of a mile) of impassable barriers were required, with approximately 160 post-hole traps distributed along them; and to destroy those already in the field before our work began it was necessary to spray a part of the northwest field with kerosene emulsion.

When these premises were taken in charge for our purpose by Mr. Taylor, June 23, 1904, the wheat was already nearly ripe, and harvesting began a few days later, continuing until July 7. The chinch-bugs were at first by no means hurried in their movement out of the wheat, as there were still grassy weeds in the stubble to detain them, and the frequent showers of the following month kept this vegetation in good condition continuously. The movement towards the corn was well marked, however, from the beginning, and prompt measures were necessary to protect that crop. There was also urgent need for a destruction of chinch-bugs already in the corn, and this was the first task undertaken, kerosene emulsion being made up to June 23 in a rather rough-and-ready manner by stirring the kerosene and soap-suds together vigorously for several minutes with a stick. This mixture was then flung on to the corn with the naked hand at a rate of about a pint to every three hills. The first mixture contained five per cent. of kerosene, and was evidently too crudely made, proving injurious to the corn, especially where it was held in the conical cavity formed by the terminal tuft of leaves. It was estimated that about twenty-five per cent. of the stalks treated on this first date were damaged more or less. A four per cent. mixture, on the other hand, as applied on the 24th of June, did no damage to the plants, and is reported to have killed the chinch-bugs as soon as it touched them. This emulsion was used from time to time throughout the whole period of the experiment in parts of two fields of corn where the bugs made their way around the ends of the barriers in number to require special measures for their destruction.

An effort was made at the very first to use a dusty furrow as a barrier, with post-holes dug in the bottom to trap the bugs, and about one hundred and sixty rods of such furrows were made June 23 to 25 on the eastern and southern sides of the northwest field, and on the west side of the four-acre patch. The ground was deeply plowed and thoroughly harrowed in a four-foot strip, and a ridge was formed by making a back furrow down the middle. A log was then dragged through the center of the strip until a dusty groove

or furrow was made several inches in depth. In the bottom of this holes were dug with an ordinary post-hole digger at intervals of twenty feet. The ground was too damp, however, even at first, to make a satisfactory barrier, and heavy rains falling on the 24th and 25th of June compelled a prompt abandonment of this part of the operation.

Coal-tar lines, substituted for the furrow because of the weather, were laid on the 24th to the 26th so far as needed to protect fields of corn on the Thorpe farm. June 30 it became necessary to lay also a similar line for a short distance along the border of the south field on the Thompson farm, as the hungry bugs were at this time crossing the road in large numbers on their way to the corn. All these tar lines aggregated about two hundred rods in length, and were maintained in an effective condition around the different fields from eighteen to twenty-eight days. It was necessary to renew them, on an average, twice every three days. One hundred and forty-five gallons of tar were used in all, at a cost of \$8.85. The supply of tar being temporarily exhausted July 9, kerosene was poured along the dried-out line on the ground, with the effect to soften it and to keep it soft for thirty hours. Besides the hardening of the tar by exposure to the sun, the barriers were occasionally bridged by dust blown into them, and broken by rains which sometimes washed them away in spots or covered parts of them with mud.

It is needless to say that no chinch-bugs crossed the tar line as long as it was kept reasonably fresh. The post-hole traps, into which the bugs were led by diagonal lines or leaders of tar, worked effectively, and bugs accumulated in them in variable amounts up to a quart for each hole. Here they were readily killed by pouring a little tar-water or kerosene upon them.

The movement of the bugs was greatly influenced by the weather. On warm and sunny days they sometimes began to travel not long after sunrise and continued until near sunset, but in cool and cloudy weather they moved later or not at all, and the traps consequently caught few or none. Whatever the weather, they never traveled at night. July 1 to 5, when the last of the wheat was being cut, they left the field more rapidly, and more of them were then destroyed than at any other time. By the 24th of July the movement was practically over, most of the bugs remaining having finished their growth and got their wings. Many of them had but recently transformed, as shown by their paler color, and pairing for the next generation was actively in progress.

The final result of the above operation is given in Mr. Taylor's report of conditions July 30, at which time he says that "all the

fields of corn which have received the protection of our barriers are quite uninjured and practically free from chinch-bugs." The small sprinkling of the insects to be found in any of the fields had doubtless flown in as they reached maturity. The actual cost for coal-tar was \$8.85, and for kerosene and soap it was \$2.55. The labor necessary to the operation was 28 days' work of a man and 2 of a team, the latter for making the back furrow, for rolling the ground, and for hauling the tar and kerosene emulsion to the field.

It should be noticed that this defensive operation was as complete and as expensive as would have been necessary if the chinch-bugs had been ten times as numerous in the wheat. That is, the labor and cost would have been no greater to protect the corn against the danger of a loss ten times as great as it would have suffered if the bugs actually in the wheat this year had been allowed to go their way.

The Fairman Experiment.—Near Fairman, in Marion county, a large field of wheat on the farm of Mr. Wm. Meredith, moderately infested by chinch-bugs, was selected for experiment. This field was bordered for eighty rods by a field of corn, from which it was separated by a wire fence. Operations were begun here June 30, when the wheat was already ripe, harvesting being in progress at the side of the field farthest from the corn. To protect the latter crop a double barrier was made within the margin of the wheat field, where two swathes of the grain were cut to give room for the operation.

A strip five feet wide the whole length of the field was plowed and thoroughly pulverized, and a deep dusty furrow was then made in the middle of it; and a strip two feet outside this was also prepared for the tar line, various parts of it by different methods.

Preparation of the Dusty Furrow.—Although wet weather prevented the continuous use of the dusty furrow as a barrier to the movement of the chinch-bugs, and compelled a reliance on the coal-tar line instead, the method used in preparing the former is well worthy of description. First, a furrow was plowed about seven inches deep and fourteen inches wide the whole length of the field in the center of the stubble border. On the return a second furrow was made immediately beside the first, the dirt from which was thrown back into the first furrow, leaving no unplowed earth between them. The land was then widened by plowing back and forth, throwing the earth toward the center each time, until six furrows had been made. This strip, about six feet wide, was then harrowed ten times with a common disk harrow, and twice with a straight-toothed harrow, leaving the ground level, thoroughly pulverized,

and free from clods and weeds. Next, near the center of this pulverized strip a deep dead furrow was made by plowing twice back and forth in the same line,—once in each direction with an ordinary fourteen-inch plow and once with a small diamond plow,—and in the ditch so made, a log eight feet long and eight inches through was dragged by a single horse (a mule would have been better) until the sides of the ditch were pulverized to the finest dust. This work would require, for an eighty-rod line, the labor of two men and a team for a little more than half a day. The average cost of a dusty furrow constructed as above described, would be practically three cents a rod, as shown by the actual labor of man and horse used on this eighty-rod line.

This furrow was finished July 3, and caught and held the chinch-bugs generally during that day and the following; but July 5 a heavy rain fell which put it out of service, and even the following day the ground was too wet to renew it by dragging again with the log. Equally heavy rains falling on the 8th and on the 11th discouraged further work with it, and it was practically abandoned in favor of the tar line.

When in use, some method of destroying the bugs entrapped is necessary. In bright summer weather the dust in the bottom becomes so hot as to kill all the chinch-bugs except those with wings, and many of these also will succumb. Otherwise, shallow pits may be dug with a post-hole digger or spade at intervals in the bottom of the furrow, care being taken to restore the dusty surfaces disturbed in this operation. The harassed bugs will accumulate here in quantities, and may be killed by pouring a little kerosene upon them. Experiments described on another page of this report indicate that the bugs caught in the dusty ditch may also be quickly killed by a brief exposure to a kerosene spray or to the flame of a gasoline torch.

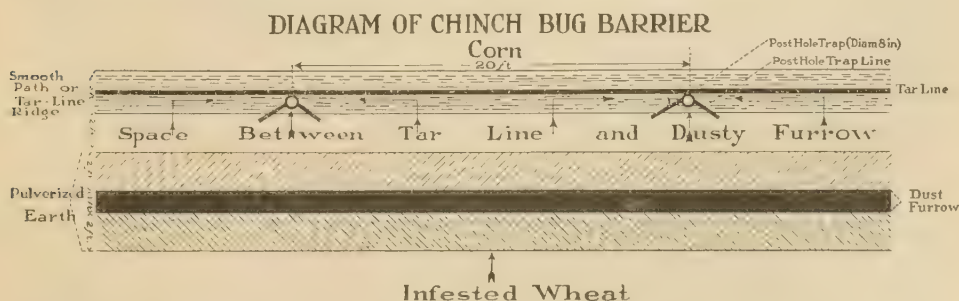


Fig. 2. Dusty furrow, and coal-tar line, with post-hole traps and diagonal "leaders" of tar

Preparation of the Coal-tar Line.—To receive the tar line it is necessary to have a smooth hard band of earth like a well-beaten path, into which the tar will not readily sink. This should be about

level with the adjacent surface or a little above, as otherwise the line is likely to be bridged by dust and rubbish blown upon it. The effectiveness of the barrier depends, indeed, largely upon the preparation of the strip of earth along which the tar is to be poured. Such a path was prepared in six different ways on as many sections of the line.

Beginning at one end, a strip ten rods long was prepared beside the fence by simply scraping smooth with a hoe and sharp spade. Where the ground is hard, and grass and weeds form a thick mat, one man will not ordinarily clear over five rods an hour. This method is laborious and expensive, and would only be necessary where a team could not be used. It would cost for labor about two cents a rod.

The second section of ten rods was prepared by plowing two very shallow furrows with a fourteen-inch plow, merely skimming away the weeds, grass, and surface roots. Both these furrows threw the dirt towards the wheat field, leaving a belt about two feet wide free from weeds and grass, and separated from the wheat by the dirt thrown over. The work was thus done rapidly, but by this method the bare strip is left lower than the general surface and is liable to be covered in places with dust and weeds by the wind. It must also be smoothed here and there with a hoe before the tar is laid down. Eighty rods can be prepared in this way by one man and a single horse in half a day.

The third section of ten rods was made ready by plowing a back furrow in the stubble and beating the ridge of earth flat and hard with spades. This was one of the most satisfactory of the methods used, as by it the tar line is placed on a ridge where it is not likely to be bridged either by winds or rains. The comparatively loose earth will at first absorb the tar more freely than the hard bottom of a furrow, but this difference is not noticeable after a few days. A ridge of this kind may be more rapidly prepared by using an inverted trough-like drag of planks, weighted if necessary, to compact the earth, as has been done in Kansas on a large scale. This will take, for an eighty-rod line, the work of a man and team for about half a day.

The fourth ten-rod section was prepared by plowing a very shallow furrow with a single horse along the edge of the grass in the headland next the fence, throwing the dirt upon the stubble. This was not a satisfactory operation, however, as it left too narrow a smooth surface.

The fifth section, forty rods in length, was prepared by simply scraping away the weed and grass roots as clean as possible with an

ordinary farm scraper, making a strip about two feet wide, one or two inches below the general level. It was necessary, however, to scrape the surface afterwards with a shovel or hoe, as many irregularities were otherwise left to carry the tar in all directions. The labor of a man and team for half a day would be required to prepare eighty rods in this way.

Finally, the sixth section, eighteen rods long, was made in meadow land by plowing two shallow furrows, throwing the dirt outward in a way to leave a level dead furrow about two feet wide, and smoothing and leveling the bottom more exactly by hand. This is a rapid and satisfactory method of preparation where a barrier can be made in sod with room to work a team.

The tar line was made by pouring from a watering can a slender stream of tar continuously along the ground. Holes were then dug with an ordinary post-hole digger to a depth of about a foot and at a distance of twenty feet apart. They were placed on the stubble side of the line, and short diagonal lines of tar were laid from each hole to the right and left in a way to conduct chinch-bugs approaching the line to the hole itself. Six gallons of tar were needed to construct this barrier along the eighty-rod boundary. During the period of twelve days covered by this experiment, the tar line was renewed eighteen times in all, as many as three times a day at first, while every other day was sufficient towards the end of the period. Fifty-five gallons of tar were used in these eighteen operations, an average of three gallons for each time. The cost of the tar for this period was \$2.40, or twenty cents a day for the twelve days. This line was of course effective from the first, and bugs were continuously caught in the holes along it, where they were easily killed with tar-water or kerosene.

Dubois and Odin Experiments.—At Dubois, in Washington county, an irregular field of corn containing twenty-eight acres was protected from invasion by chinch-bugs from two fields of wheat adjoining it. On the east side along a boundary line of two hundred and fifty yards a double barrier was constructed, a furrow next the corn and a tar line with post-holes immediately outside. To the west and north a tar line was laid seven hundred and sixteen rods in length, and post-holes were dug every twenty feet. Although the chinch-bugs proved not to be sufficiently numerous in the wheat to have caused any great injury even if they had escaped into the corn without hindrance, these barriers were as carefully maintained for eleven days, from June 29 to July 10, as if the salvation of the corn depended upon their efficiency.

At Odin was a small field of infested wheat, containing four acres, with corn bordering it to the north and west. A tar and post-hole line was carried along these two sides for about a thousand feet to prevent the passage of the bugs across the boundaries.

The conditions and results at both these places were so similar to those at Fairman that no detailed account is necessary. At Odin a simple method was made use of for preparing the ground for the tar. A heavy plank was dragged endwise back and forth about ten times along the edge of the wheat, thus smoothing and packing well a strip two feet wide. With a short-handled shovel the ground was then packed and pounded to a hard surface, in which a narrow and shallow groove was made with the shovel handle for the reception of the tar. This was poured in a stream the size of a lead-pencil from the spout of a watering-pot from which the sprinkler had been removed. The line so laid spread out on the ground to a width of a half to three quarters of an inch.

EXPERIMENTS WITH FLUID INSECTICIDES.

In my first report, the twelfth of this office, published in 1883, is a description of the first attempts made to destroy chinch-bugs by means of kerosene mixtures. In the operation there reported, nineteen experiments were made, mainly with emulsions varying in strength from two and a half to six and two thirds per cent. of kerosene, but partly with mechanical mixtures of the crudest kind.

These insecticide fluids were sprinkled upon infested hills of corn during the last days of July, partly transplanted hills which had been removed to my office laboratory and partly hills in the field isolated by surrounding them with barriers of boards and coal-tar impassable to insects on foot. Proper checks were kept in all cases of hills treated precisely like those under experiment except that plain water was substituted for the fluid insecticides. A single additional experiment was made with strong soap-suds to which no kerosene had been added.

The general result of a single application of any of these mixtures was the destruction of about eighty per cent. of the bugs on the corn at the time, the remaining twenty per cent. being either protected by their position from contact with the insecticides or reviving after a time without noticeable injury. Most of the escaping specimens were apparently on the ground under clods of earth when the corn was treated.

Frequent use has since been made of the kerosene mixtures in field experiments by ourselves and by other entomologists, partic-

ularly for the destruction of chinch-bugs accumulating on the outer rows of corn as they move into the fields from wheat or oats at harvest-time. This insecticide method, however, is mainly useful as an adjunct to the barrier method already described.

With a view to testing this operation on a comparatively large scale, I instructed Mr. E. P. Taylor, in charge of my field operations against the chinch-bug in 1904, to prepare and apply kerosene emulsion in the field wherever necessary and practicable in his operations, to keep an account of labor required and the cost of materials, and to observe critically and report the effects of the treatment upon both insects and plants. Experiments of this kind were made in early July of that year with both kerosene emulsion and whale-oil soap.

In the absence of a mixing pump, the kerosene and soap-suds, two parts of the first to one of the second, were thoroughly mixed by a simple violent beating with a stick for about five minutes, the vessels containing the fluids being covered with a cloth to prevent spattering. Emulsions so prepared, although doubtless not so perfect as could be made with a pump, were in every way sufficient for the purpose, standing for at least two hours without any appearance of a separation of the oil and water, and doing no damage whatever to the corn if diluted to contain four per cent. of kerosene. If more than this proportion of the oil were used, injury to the plant was likely to result, especially if the upper leaves were treated.

Details of Field Experiments.—At Fairman, July 4, one fifth of an acre of corn was sprayed with a kerosene emulsion prepared as above and diluted to contain four per cent. of kerosene. No apparatus was used in making the application, but the fluid was simply flung upon the corn by hand. Ten gallons of the mixture were used in this treatment, equivalent to about a barrel (fifty gallons) per acre, or approximately one and two thirds ounces per hill. The amount of kerosene in a four per cent. mixture used at this rate would be two gallons per acre of corn treated.

Twenty-four hours later none of the plants showed signs of injury, and great numbers of the bugs were dead upon the ground and in the cups at the bases of the leaves. Living chinch-bugs enough remained in this part of the field to extend their attack gradually inwards, until by July 9, five days after treatment, they were to be found in small numbers ten rods beyond the area infested at first. The number remaining, however, was economically insignificant, since no injury to the corn could have resulted.

A second treatment was applied July 12 to this whole area, now about three fourths of an acre in all, twenty-four gallons of the

mixture being used. A part of the corn was now about two and a half feet high, and the chinch-bugs were mainly behind the leaf-sheaths or within the conical cavity at the tip of the plant. The kerosene mixture was applied in part by hand as before, and in part by pouring from a common sprinkling can, but the former method was found the more rapid and also the more economical of material.

As shown by examination the following day, not a plant was injured by this treatment, and only a few bugs were left alive, mainly on plants with leaves so rolled and curled as to protect the bugs within them. A careful count was made of all the bugs, living and dead, found upon ten average hills, including those on the ground about the bases of the plants, with the result that eighty-eight per cent. of all found were dead. An additional treatment was given to the corn still infested, and July 24 the owner of the field, after a careful examination, found an average of twenty to twenty-five living bugs per hill. The corn was at this time beginning to tassel. The same treatment, would, of course, have destroyed any number of chinch-bugs with which the corn might have been infested. As the three quarters of an acre invaded by the bugs was part of a forty-acre field much of which would have been infested and injured if this section had not been promptly dealt with, the result of the treatment was much greater than the protection of the corn actually covered by it. At the rate at which this treatment was applied it would take two hours to treat an acre, or an average of five acres per day.

At Odin, experiments were made July 6 with solutions and mixtures of various strengths to test the effect upon both insects and corn. The plants were young—only about six inches high—and the liquid was thrown upon them by hand, care usually being taken, however, to avoid filling the cavity at the tip of the plant. The emulsions were made by beating, as before, the kerosene being heated before adding it to the soap solution.

Kerosene emulsion was applied in dilutions varying from four to ten per cent. of kerosene, and whale-oil soap was used in solutions varying from an eighth of a pound to two pounds to the gallon of water. With a four per cent. kerosene emulsion applied in a way to drench the entire plant and fill the cavity within the terminal tuft of leaves, no injury whatever was done to the corn, and the chinch-bugs were nearly all killed. A similar treatment with a five per cent. emulsion, however, was injurious to the plants. Some leaves were wilted at the base the following day, and seventeen out of the thirty plants treated were finally killed. Still more serious injury of course followed the use of the stronger mixtures.

Whale-oil soap dissolved by boiling at the rate of a third of a pound to the gallon of water proved too weak to destroy more than a comparatively small percentage of the bugs. With a half-pound to the gallon, the bugs reached by the liquid were practically all destroyed, and none of the plants were killed except where the terminal cavity in the so-called heart was filled, in which case the concentration of the solution due to the gradual evaporation of the fluid caused the leaves to wilt and destroyed the plant. Three quarters of a pound to the gallon was perhaps a little more effective as an insecticide, but somewhat more dangerous to the plant. A few plants which were carefully treated were seen six days afterward to have been injured slightly, the injured leaves rolling up or growing in distorted forms. Where as much as a pound and a half per gallon was used nearly all the plants were killed, and two pounds per gallon was fatal to every one.

From the above it appears that a solution of whale-oil soap—one half pound to the gallon—is a safe and successful insecticide for corn-field use. As its cost, however, is about three times that of the four per cent. kerosene emulsion, it is scarcely to be recommended except on the score of occasional convenience. Where a barrel of the four per cent. emulsion costs thirty-four cents, a barrel of a half-pound solution of whale-oil soap will cost \$1.12.

Such fluid insecticides may best be applied during the cooler parts of the day, since the plant is less subject to injury then and the bugs feed more thoroughly. Enough of the liquid must be applied to wet the insects thoroughly, since otherwise they are likely to recover from its effects. For a complete operation, two and even three applications may sometimes be necessary.

EXPERIMENTS WITH THE GASOLINE BLAST-LAMP.

The use of the ordinary plumber's torch, or some modification of it, for the destruction of injurious insects on their food plants seems to have occurred independently to several persons during the last few years, and to have been tried with some care as a practical measure by several disinterested men competent to make exact observations and to report results without bias or prejudice.

Mr. S. A. McHenry, recently superintendent of one of the horticultural substations of the Texas Agricultural Experiment Station, is reported to have used it for several years against the harlequin cabbage-bug, and Professor J. M. Stedman, of the Missouri Experiment Station, has also used it against the same insect. Professor R. H. Pettit, of the Michigan Agricultural College, tried it on the

San Jose scale as far back as 1897, publishing in the Bulletin of the Michigan Experiment Station the earliest report of an exact experiment with it which I have seen; and Professor Craig, of the Horticultural Department of Cornell University, has also tried it on this scale. Professor E. D. Sanderson, formerly of the Texas Agricultural College and Experiment Station, has used a form of it on the cotton boll-weevil. Professor Thomas B. Symons, of the Maryland Agricultural College and Experiment Station, used it experimentally on the San Jose scale, and on beetles infesting the aster. Professor J. L. Phillips, State Entomologist of Virginia, has also tested it on the San Jose scale with unusual thoroughness; Professor F. M. Webster, Entomologist of the Ohio Agricultural Experiment Station, had it tried four years ago by an assistant, Mr. C. W. Mally (now Government Entomologist in Cape Colony, South Africa), on a variety of insects, including the chinch-bug; and two of my own assistants, Mr. E. S. G. Titus and Mr. G. I. Reeves, have used it on scale insects, caterpillars, and moths; have tested it for the destruction of fungus parasites of the green leaf; and have determined its effects on various kinds of vegetation when applied in a way to kill the insect enemies of the plant. Most of these experiments are unpublished, but their results have been generously placed at my disposal for use in this brief discussion.

Although no one of those here mentioned has made a trial of the gasoline torch for all the insecticide and fungicide purposes which it might possibly serve, the total results have a considerable value as showing definitely some things which can and some things which can not be done with it, and as indicating the directions in which further trials may be had if indeed it appears that further trial is necessary or worth while. Some variation and conflict in the reports of some of these experiments are evidently due to differences in the apparatus used, this varying from a poorly constructed and feeble torch, made in Illinois especially for insecticide work, to a large and powerful blast-lamp, used in Texas for burning the thorns off prickly pears.

The idea that exposed insects of small size may be quickly destroyed by the sudden and brief application of a blast of very hot air, or even of actual flame, without injury to the plant on which they may be feeding at the time, strikes one favorably at first thought; and there seems, in advance, to be no obvious reason why this method may not have a considerable practical value. The living animal is often more sensitive to sudden heat exposures than the living plant, and the margin between exposures fatal to each may in some cases be so wide as to make this method fairly safe in

ordinary practice. The smaller the insect, of course the more quickly it may be killed by the hot blast; and the better the living tissue of the plant is protected by a lifeless cuticle or a layer of bark, the longer it may be exposed to this blast without being heated to the point of injury. Bark-lice on trees and shrubs are thus favorable objects for experiment; but where thick-bodied insects, like caterpillars and large beetles or bugs, themselves covered with a dense crust of lifeless cuticle, are feeding on the young green leaf, the margin of safety is greatly narrowed and may wholly disappear. The practical utility of this method of destroying insects in any case, evidently depends on the existence and extent of this margin of safety.

The gasoline blast may, in fact, be used to kill any insect on any plant. The time and method of use necessary to kill the insect will vary widely for different kinds of insects and for the different states and stages of each kind; and the time and method of use sufficient to injure various kinds of plants will likewise differ widely according to the kinds and condition of the plants themselves. The actual effect of the blast on either insect or plant will also vary enormously according to small details of the method by which it is applied. They will vary, first, with variations in the pressure, which determines the extent and heat of the flame; second, with the distance from the object at which the torch is held; third, with the rate of movement at which the flame is passed over the surface treated; fourth, with the temperature at the time and the amount and direction of the wind; fifth, with the direction of the blast, whether perpendicular or oblique to the surface; and sixth (not to specify further), with the steadiness with which the flame is applied to a given surface, whether held at one point for a definite time or swayed back and forth over a considerable surface for a variable number of times.

To determine the effect of all these different classes of variations with sufficient exactness for practical guidance, and then to combine all the various results of this inquiry with each other in a way to form a system of practice which can be accurately described and safely recommended for general use, is a task which no intelligent investigator would enter upon lightly, or without such preliminary tests as would enable him to judge whether any important result was likely to come from more exact and extensive experiments. The observations here reported are all in the nature of such preliminary tests, made by different persons, each for his own satisfaction, on different objects and in different parts of the country. They are practical tests rather than complete scientific experiments, and

their value is hence suggestive rather than final. Those which have to do with the San Jose scale, the harlequin cabbage-bug, and the cotton boll-weevil are perhaps of the greatest interest, and will be given first.

The San Jose Scale.—In the fall of 1897, Professor Pettit, of Michigan, had five parallel burners fitted to an ordinary plumber's blast-lamp in such a way that a flame about ten inches wide could be directed against the surface of a tree, and several trials of this apparatus were made during the following winter on peach- and pear-trees badly infested with the San Jose scale. "The heat produced by this lamp," he says, "is very intense, and great care must be observed not to allow the flame to remain at any one point long enough to injure the tree. The best results were obtained when the flame was steadily moved so that it covered a space of a yard in length in from five to ten seconds. The results seemed to show that the blast will kill the scale-insects with little or no injury to the tree. The trees were scorched in places where the flame had moved too slowly, and the care necessary to avoid the scorching appears to be the most serious drawback to the use of the blast lamp. In careless hands much injury may be done in a very short time, while the skilful handling necessary for success would be rather expensive under ordinary circumstances. Good judgment must be exercised always, and the rapidity and effectiveness of the work will be much modified by the temperature of the air, the direction and force of the wind, the age of the trees, and the thickness of the incrusting scales." Referring to these statements in a recent letter, Professor Pettit writes that he intended that the lamp should be used only in connection with a spray, for burning off or loosening the outer layers of a crust of scales so that a fluid insecticide might penetrate to those beneath. "I now realize," he says, "that the same effects may be obtained much more cheaply in other ways."

By Professor Craig, of Cornell University, a torch much advertised for the destruction of insects was used May 19, 1903, against the San Jose scale on the apple, medlar, buffalo-berry, and dog-wood. Different branches were flamed in various ways to ascertain the time necessary to kill the scale and to determine the minimum exposure to the flame of the torch which would kill the cambium layer of the tree or shrub. In respect to time of exposure three methods of treatment were used: passing the flame so rapidly over the surface that it merely touched each point for an instant; moving it at the rate of one foot per second; and holding it stationary on the infested spot long enough to count one. The scales were reported to have been killed in every case save one, in which a twig of dogwood had been

very rapidly flamed. "The general results," writes Professor Slingerland "were summarized as follows: First, the torch is impracticable for large trees of apple, plum, pear, peach, or cherry, because of the amount of time required to flame the whole tree. It would take a man several hours thus to go over one large tree; second, there is great danger of injuring buds or the cambium layer on thin-barked trees; third, the torch might be used on small nursery stock or ornamental shrubs by an experienced operator who knew exactly what time to expose the plant to the flame."

Professor Phillips, of Virginia, made use, against the San Jose scale, in 1903, of a torch sent by the manufacturing company for trial to Professor Alwood, of that state. "March 28, of this year," he says: "I used this gasoline torch on two apple-trees four years of age. These trees were moderately infested with the San Jose scale, and were treated by running the torch over the surface several times. One tree was exposed to the torch about twice as long as the other. This treatment did not appear to injure the trees, neither did it kill a perceptible number of insects."

"I was not satisfied with this trial, however, and detailed a student assistant, Mr. E. F. Cole, to test the torch, which he did August 7. The tree treated was a four-year-old apple, badly crusted with the San Jose scale. As it would be entirely impracticable to use this torch against the San Jose scale during the summer, this treatment was confined almost entirely to the trunks and main branches of this tree, but in treating the tree in this manner, of course a few of the leaves were also reached by the flame. The treatment was so severe that the leaves on the treated portions of the tree were killed at once, and when examined on August 20, portions of the bast tissues of the bark were found injured also. Quite a large number of scale insects were alive at that date."

"Judging from these two tests, I consider that the use of this torch is quite tedious and impracticable, even on small trees. Besides, such a small per cent. of the San Jose scales were destroyed by it, even where the trees were seriously injured by its use, that I do not consider it a practicable remedy."

Professor Symons, of Maryland, writes me that he personally conducted some experiments with the same kind of a torch on different varieties of peach and plum infested by the San Jose scale, but that the results were not at all satisfactory. Although the insects were dead two weeks later on the parts which had been hit by the flame, young scales were crawling about over the surface in considerable numbers, showing that it had been impossible to reach all parts of the tree, especially at the ends of the branches. If used

when the tree was in leaf he could not avoid burning the foliage. As a result of his experiments, Professor Symons concludes that it is impracticable to control the San Jose scale with this torch.

To these observations by experts I may add a note of a trial of the torch made by a practical gardener on some infested trees belonging to J. W. Stanton, of Richview, in this state. By oversight, these trees were sprayed with whale-oil soap before they had been critically examined as to the final effects of the blast on the San Jose scale; but Mr. Stanton writes me that from what he could see of the effects of the treatment at the time, he is of the opinion that it would not be successful on tree fruits. One of my horticultural inspectors, Mr. R. W. Braucher, happened, however, to examine one of these trees after the treatment with the torch and before the application of the whale-oil soap, and found that the bark was scorched in some places, and that in others the scales were still alive.

From the foregoing experiments, it is clear that the gasoline torch has at best only a very limited application in the treatment of trees infested by the San Jose scale. It might be occasionally used to advantage, as suggested by Professor Pettit, to burn off the outer part of an unusually thick crust of scales on the trunk and largest branches of a tree, preliminary to a treatment with the lime-and-sulphur wash. As this insecticide does not penetrate readily to any great depth, it is sometimes necessary to repeat a spraying after a time if the tree is too thickly incrustated. This second spraying might perhaps be omitted if the torch were first used on the crust of scales. It would be the merest folly, however, to think of using it as a substitute for an insecticide spray in the treatment of the San Jose scale, or for any general treatment of orchard trees for any purpose whatever.

This torch was also tried on certain other orchard scales at Urbana during the fall of 1902, but for reasons to be given presently these tests are reported separately farther on.

The Harlequin Cabbage-bug.—The introduction of the use of the gasoline torch against the harlequin cabbage-bug in the South seems to be due to Mr. S. A. McHenry, recently superintendent of one of the substations of the Texas Agricultural Experiment Station. Indeed, Professor Sanderson, when official Entomologist of that state, wrote me that, so far as he knew, Mr. McHenry was the first man to make practical use of the blast torch against insects of any kind. He is said to have used it successfully for several years, as have others in his section of the state, but of late he has made

comparatively little use of it for that purpose because of the amount of work required to go over a cabbage plant with the torch.

Professor J. M. Stedman, of Missouri, writes more confidently of its usefulness against the cabbage-bug, saying, under date of October 28, 1903, "I have not found the gasoline torch of any special value as an insecticide apparatus except in extreme cases when one has a sufficient number of the harlequin cabbage-bugs in his cabbages to cause serious trouble. I have then used this torch to good advantage. One can very readily pass over the cabbages fast enough not to injure them, and at the same time to kill the harlequin bugs. It is not necessary to have the bugs scorched sufficiently to drop at once, as I have found that they will ultimately die if this intense heat has been very rapidly applied."

This cabbage-bug is not widely destructive in this state, although it is continuously present in some parts of southern Illinois, and during one season extended its injuries as far north as Champaign, and was once found in Chicago by Mr. A. Bolter. The reported effectiveness of this torch against this insect suggests the trial of it against other bugs, which cannot be killed with arsenical poisons since they do not eat the solid substance of their food plant but merely suck its sap.

The Cotton Boll-weevil.—The appearance in Texas of the snout-beetle known as the Mexican boll-weevil has caused general and justifiable alarm among the cotton-growers of the South, and the former Texas State Entomologist, Professor Sanderson, has devoted himself to an assiduous study of the insect and has made many experiments for its destruction and control. This is indeed the most important, pressing, and perplexing problem which the economic entomologist now has to deal with in the Southern States. In the course of his work against this insect Professor Sanderson has tried two forms of the gasoline torch; one, a blast-lamp known as the pear-burner, used in southwestern Texas for burning the thorns off the prickly pear, and the other a torch sent him from Illinois by a dealer who offers and advertises it for sale for the destruction of insects. The latter was found so faulty in construction that it could not be used, and it was consequently returned.

The pear-burner, which generates a much more powerful blast than any of the smaller torches, was tried by Professor Sanderson for burning up the squares of the boll-weevil as they lay upon the ground, but so far, as he writes me October 28 of this year, he has not had sufficient success with it to indicate that it has any value for this purpose.

The only other beetles on which it has been tested by any of my correspondents are certain unspecified species found on aster by Professor Symons, of Maryland. "In this case," he says, "it was effective in killing the beetles, but one has to be so extremely careful not to hurt the flowers that I would hardly recommend it for practical use."

Experiments at Urbana.—In response to my request, made August 5, 1902, to the inventor and patentee of a modified form of the gasoline torch intended especially for insecticide work, one of his instruments was sent me with directions for its use, and was at once put into the hands of my most experienced field assistant, Mr. E. S. G. Titus who, with the aid of another assistant, Mr. George I. Reeves (both now assistants to the United States Entomologist), tried it at various times during the following two months on such kinds of injurious insects as could be found in any number at Urbana at that time of the year. It was further tried on a fungus parasite of the lilac leaf, and on various kinds of vegetation to determine the effect on the plants of an exposure sufficient to kill the insects infesting them. Although sent me expressly for experimental purposes, this instrument proved to be relatively so weak in action that its use by us should probably be regarded as a test of the value of this kind of a torch rather than that of the torch method in general; and it is on this account that I have kept our own statements separate from those made to me by others, most of whom seem to have worked with a more efficient apparatus.

The results of our various trials are here given as reported to me by Mr. Titus at the close of his series of experiments, about October 20.

"The torch is simply an ordinary 'plumber's torch' fitted with a two-gallon gasoline tank and a three-foot piece of rubber tubing. A short iron discharge-pipe connects the rubber tubing with the torch.

"Filled the tank about half full of gasoline according to directions. The valve in this pump was of leather and by no means circular in outline, and it was at first rather hard to secure even pumping pressure. The connections were all very dry and needed soaking. After an hour or so of work, cleaning the discharge-pipe and burner, we were able to light the latter and get a flame.

"Under the heaviest pressure obtainable—sufficient to force air bubbles from the pump valve and at the cut-off in the base of the pump—the flame was tried at varying distances. At fifteen inches from the burner the heat was scarcely sufficient to singe the hair from the hand, but a little closer, ten to twelve inches distant,

it would singe. The burner was used when running at full force. The effects were about as follows, examinations being made at several days' intervals:—

“The trunk and smaller limbs of an apple-tree were thoroughly treated. This tree was badly infested with Forbes and scurfy scales, and also had on it considerable woolly aphids. The last-mentioned insects were killed where they were completely burned off the limb; but where only the woolly covering was burned off, and the insect not actually caused to drop, there was little apparent injury. The Forbes scale appears not to have been injured, except the young not yet old enough to form a scale. The scurfy scale was not injured. The smaller limbs were sufficiently treated to cause the bark to blister in spots, without having any apparent effect on mature scales of either kind.

“I have tried the burner under ordinary pressure at different times against various other insects and foliage. A colony of fall web-worms in a box-elder tree was treated, and a number of worms that fell were placed in a cage in the insectary. These were given plenty of fresh food, and did not appear to be inconvenienced by the lack of hairs on their bodies. They grew, and some of them pupated. Most of the remainder were parasitized, and the few that died were full grown at death. The parasites emerged in due time and were preserved.

“Arctian caterpillars (woolly bears) treated to the full force of the burner for ten to fifteen seconds, or even longer, had the hair thoroughly singed from their bodies, and some were blistered. The majority of these finished their growth and pupated. I could see no greater mortality among them than ordinarily occurs with this species under insectary conditions. Several cabbage-worms were treated until they rolled from the leaves. Most of these were not permanently injured, and those that died were burned so badly that the outer skin was broken. To produce this effect upon a caterpillar it must be treated with a direct blaze long enough to cause the leaves to curl and blacken on the plants.

“Meadow moths (*Crambus*) flying about in the grass were singed with the flame. Some of these would fly through the flame so close to the burner that the hair on one's hand would be quickly singed off, but they were usually uninjured by this experience. To kill one of these moths it had to be followed with the flame until some parts were burned sufficiently to cause it to fall, when it could of course be easily disposed of.

“Lilac leaves badly infested with mildew were thoroughly treated, the burner being held at varying distances and acting for

varying periods of time. The mildew does not seem to have been affected where the leaves were not injured, and was rarely affected where the leaves were burned sufficiently to cause them to curl and later to wither. Leaves that were treated to the flame for three seconds dropped off. Other leaves treated one second remained on the bush and were not perceptibly injured. Between these two times (which really represent flashing the burner over the surface and holding it there for an instant) the leaves show varying injuries. At first the mildew appeared to have been burned off, but specimens which had been thoroughly treated and left in the insectary were again covered with the mildew in five days.

"Elm, Osage orange, box-elder, apple, cherry, plum, grasses, nasturtiums, cabbage, pine, cedar, *Amorpha*, walnut, rose-bushes, peach, and several other trees and ornamental shrubs have been treated at various times. I find that when the flame is held close to the foliage for a few seconds this is visibly injured. If held a short distance away the injury is not so great, but usually shows after a few days by the blackening of the leaf or by the browning and curling of the edges. Often leaves so treated will drop off.

"To sum up: The use of sufficient heat to destroy effectually insect larvæ of the kinds we treated, will injure the foliage and often the twigs."

Mention may be made of a trial of the torch by Mr. Mally, in Ohio in 1898, the details of which can not now be given because the record is not accessible. This torch, obtained from Illinois, was put into Mr. Mally's hands by Professor F. M. Webster, with instructions to give it a thorough test. It was taken by Mr. Mally on one of his field trips, used on a variety of insects, including the chinch-bug, and returned with the general report that it was unsatisfactory for its purpose.

USE OF THE GASOLINE TORCH AGAINST THE CHINCH-BUG.

Notwithstanding the generally unfavorable character of the statements made to me concerning this torch by those best able to judge of its value, it seems that it may have a field of usefulness for the destruction of certain kinds of injurious insects. Thinking that it might profitably be tried in comparison with other aids to the trap and barrier method for the destruction of chinch-bugs as they come out of small grain in midsummer, I provided for a series of field trials with a first-class torch, in connection with other experiments on the chinch-bug made during the summer of 1904. To make sure of having a good example of this form of blast-lamp, one

was bought from the manufacturer in person, who was kind enough to give careful instructions and to illustrate personally its use in the field.

Two miles south of Carbondale was a field of forty acres of corn adjoining wheat infested by chinch-bugs, which had almost completely destroyed the corn on an area two hundred and twenty yards long and seventy yards in depth. Only a few scattering hills remained on this strip, and a good deal of this was lying almost flat on the ground. Farther within the field the corn was only moderately infested, but was of course still liable to serious injury by the invading host. July 30, when this experiment began, most of the bugs had developed wings, though many were still to be found in all stages from the very young to the lately transformed adult.

The lamp was first used on fallen hills thickly covered with the bugs, many of which, however, were concealed within leaves closely rolled for their entire length. When the blast of flame was turned upon the corn, many bugs exposed on the surface of the plants fell to the ground, where they could easily be killed by following them with the flame. Many others, however, would not leave their shelter among the leaves, and these were left uninjured.

Where the field was only moderately infested, scattered adults and clusters of them exposed to the flame dropped to the ground at once, where they could be quickly destroyed; but many dropped from the side of the hill farthest from the torch, where they could not be reached until the operator returned down the other side of the row, as only one side of the hill could be treated at once. Indeed, for a satisfactory application of this method it would be necessary that two men should take a row together, one on each side, operating against each hill simultaneously. Even this would not wholly prevent the premature escape of the bugs, as many fell from the corn two or three hills in advance of the roaring blast and hurried away in an effort to escape. Those which remained secreted behind the ensheathing bases of the leaves were also, of course, protected from injury. In this respect the blast-lamp proved less efficient than the kerosene emulsion, since the latter was especially useful in reaching the accumulations of chinch-bugs hidden behind the leaves.

For a more accurate test of the effect of the hot blast ten cages were arranged in such a way that the bugs could be treated within them and held captive under normal conditions for observation afterwards. In one of these cages two hundred and fifty chinch-bugs, mainly adults, were flamed with the exit of the blast held for one second an inch from the bugs, the pressure having been pumped up about to a maximum by two hundred strokes of the piston. The

following day eighty per cent. of the bugs were dead, together with several adult blister-beetles (*Epicauta marginata*) and Colorado potato-beetles treated at the same time.

In another test like the preceding, except that the bugs were exposed to the blast for two seconds, eighty per cent. were dead the following day. A third experiment duplicated the first with a result to kill eighty-five per cent. of the bugs. In a fourth cage the flame was held for a second two inches from the bugs, and the following day seventy-five per cent. of the two hundred and fifty treated were found to have been killed. At a distance of four inches the flame killed but ten per cent., the remainder crawling about, apparently uninjured, twenty-four hours later. An adult potato-beetle and two larvæ of the same, a common cabbage-worm, and a caterpillar of the cabbage *Plusia* were likewise uninjured by this treatment. In another experiment it was shown that if the burner were held three seconds at a distance of four inches from the insects, only ten per cent. of the chinch-bugs were killed.

A thousand chinch-bugs were next exposed to a gentle blast of the gasoline flame until they were all unable to crawl. On the following day about fifty of them were still able to move, although the legs and other appendages of some of these were scorched.

In order to ascertain whether the bugs might die from the after-effects of the blast, a thousand specimens in another cage were subjected to an extreme scorching heat without killing them at the time. On the following day at least half of them crawled away, evidently uninjured. Another lot of a thousand were flamed until a third were killed outright, the remainder being rapidly flamed several times but left able to crawl away. On the following day at least two thirds of the bugs were alive. From these experiments it appears that bugs not killed at the time of treatment do not ordinarily die thereafter. A lot of two thousand chinch-bugs or more, collected from corn and confined in a similar cage, which were kept as a check during the course of these experiments, lived with less than one per cent. of loss, and these were probably injured in collecting.

To determine the resisting power of the corn to the hot blast of the gasoline torch several plats, equally infested and all in one field, were treated variously. The flame was moved over the plants sometimes quickly, sometimes slowly, and was sometimes held close to the leaves, sometimes at a greater distance. In this experiment the unit was a plat of a hundred hills of corn, which averaged three feet high at the time. All plats were treated in the afternoon of July 30, the weather being clear and hot, with a little wind. The lamp was used at a high pressure, produced by two hundred suc-

cessive strokes of the pump. The heat was sufficient to scorch the hairs from the back of the hand at twelve inches from the burner, and to burn in two in thirty seconds a stalk of corn held four inches from the nozzle.

In the first plat the flame was passed steadily upward for a foot along the stalk at the rate of about two feet per second, this flaming process being four times repeated for each side of the hill with the nozzle held an inch or less from the plant. Each plant was thus exposed to the blast for four seconds in all, a half a second each time. Two days later some of the bugs were dead, but many were still alive, and many stalks of corn were seriously injured, scarcely a hill in the plat having wholly escaped scorching. In some hills the large leaves were burned, and in nearly all the lowest leaves were visibly scorched.

This experiment was repeated on another plat except that the tube was held about four inches from the plants. Two days later the corn was less injured than in plat one, but nearly all was scorched more or less, especially the upper leaves. Some of the bugs were still alive, probably those which fell to the ground and escaped and those secluded beneath the sheaths of the leaves.

In another plat the treatment was varied by flaming the bugs at the base of the plant as they fell upon the ground, using on an average two seconds additional for each hill. The torch was handled about as in the first experiment, and the plants were similarly injured. The hardened cuticle at the base of the stalk was less likely to be scorched than the green and tender leaves. The bugs were nearly all destroyed on this plant, although a few were still alive the following day.

By other experiments it was found that by two or three treatments, separated by intervals sufficient to allow the escaping bugs to collect again, the corn might be almost completely cleared of bugs, but, unfortunately, without the most painstaking care injury to the plants was such as to make this form of treatment quite inadmissible.

The cost of these operations was considerably less than the corresponding treatment with kerosene emulsion. The time required was practically the same, but the cost per acre was thirty-four cents for the emulsion and fifteen cents for the gasoline.

It was Mr. Taylor's judgment that two treatments with a four per cent. emulsion would have about the same effect upon the bugs as three applications of the torch, but the latter is more convenient to use, requiring no previous preparation of the fluid and no hauling of water to the field. The risk of injury to the corn is of course

much greater with the torch—especially in the hands of unskilled or careless workmen. The price of \$10 charged for the blast-lamp would determine the choice of many, since apparatus may be wholly dispensed with in the preparation and application of the kerosene emulsion.

There is an evident use for the gasoline torch in the destruction of bugs collecting either in the dusty furrow or along the coal-tar line, where these are used as barriers against the movement of the chinch-bugs from small grain to corn. By directing the hot blast against the insects trapped in the furrow or collecting along the tar line on the ground, these could be rapidly killed at small expense, and the post-hole traps might thus be dispensed with. Care would be necessary, however, to prevent the burning or drying of the tar by the flame.

It also seems quite probable that a fine spray of pure kerosene, or even of crude petroleum, might be used to good advantage for the destruction of the chinch-bugs on the ground, and perhaps at less expense. On the coal-tar line the kerosene might be preferred because it would tend to soften the tar and lengthen the period of its efficiency as a barrier, and could not dry and harden it as would the flame. Opportunity was wanting last season for experiment covering these last suggested points, and they must consequently be tested at some other time.

At a later date the blast-lamp was used in the potato field to destroy the adults and larvæ of the common potato-beetle. For this operation it was found entirely impracticable. The insects could of course be killed, but at an expense of about fifteen hours of labor per acre.

GENERAL SUMMARY.

These experiments may be considered as a test of the efficiency of barriers constructed to arrest the movement of chinch-bugs in passing from small grain to corn at harvest-time, under conditions unfavorable to success, that is, when the chinch-bugs were not so numerous as rapidly to destroy the wheat—compelling their migration en masse—and when the weather was neither extremely hot nor very dry. The spring and early summer of 1904 proved to be unusually wet, and chinch-bugs consequently were not generally abundant enough to threaten any great injury to corn. The weather also prevented the use of the dusty furrow, most commonly resorted to as a barrier to the movements of chinch-bugs, and compelled a reliance on the coal-tar line with post-hole traps instead. So far as the season permitted a real test of the operation, it was completely

effective for the protection of corn, and there is no doubt that it would have been equally so if chinch-bugs had been ten or a hundred times as numerous.

A partial failure of the experiment due to the character of the weather of the season did not diminish its value as a means of determining the cost of an effective operation on the scale of actual farm practice. It was demonstrated that the coal-tar strip may be laid down and maintained for four weeks—the maximum period necessary—at a cost of \$22 a mile, with the effect to trap all bugs approaching the line, where they may be readily and rapidly killed. The average cost of making a dusty furrow or ditch sufficient to arrest and trap all chinch-bugs attempting to cross it was approximately three cents a rod, or \$10 a mile, for labor only, no materials being required. This furrow can not be used, however, except in dry hot weather.

Various methods of preparing the ground for the coal-tar line were used in comparison. One of the most satisfactory methods was that of plowing a back furrow in the stubble near the edge of the field, and packing this with a roller or beating it flat and hard with spades. A strip of sod may be prepared to receive the line by scraping away the grassy surface with an ordinary farm scraper, afterwards leveling and smoothing it carefully with a shovel or hoe.

A kerosene emulsion prepared by mixing two parts of kerosene and one of soap-suds by violently beating with a stick for about five minutes, and diluting to contain four per cent. of kerosene, was found efficient for the destruction of all the chinch-bugs touched by it, and was successfully used for clearing rows of corn along the borders of a field which had become infested for lack of effective barriers. Stronger kerosene mixtures made in this way commonly proved injurious to the plant. A barrel of diluted emulsion costs about thirty-four cents. It was applied to the corn by hand at an average rate of a barrel an acre—five acres per day for each man. A solution of whale-oil soap, one half pound to the gallon of water, proved to be a safe and sufficient insecticide for corn-field use. Its cost was \$1.12 a barrel.

The gasoline blast-lamp, tested on a great variety of insects, was found to be only occasionally useful. By two or three successive treatments separated by intervals sufficient to allow the chinch-bugs which escape to collect upon the plant, badly infested corn might be almost completely cleared of bugs, but serious injury to the corn itself was almost certain unless the most painstaking care was used. The cost of material is less than that of kerosene, amounting to only about fifteen cents an acre for each treatment with the

former and thirty-four cents for the latter. Three applications with the torch were about equal to two treatments with the kerosene emulsion, the first being most convenient to use but also most dangerous to the plant. It is suggested that this gasoline torch may be found a convenient apparatus for destroying chinch-bugs collecting either in the dusty furrow or along the coal-tar line, when these are used as barriers.

COMPARATIVE EXPERIMENTS WITH VARIOUS INSECTICIDES FOR THE SAN JOSE SCALE.

In my Eleventh Report as State Entomologist, published in 1903, I gave the results of experiments and extensive practical operations with several of the more prominent insecticides used against the San Jose scale,* including whale-oil soap solution, hydrocyanic acid gas, kerosene emulsion, mechanical mixtures of kerosene, and lime and sulphur compounds known as the "California wash" when made with the addition of salt, and the "Oregon wash" when made with blue vitriol. All these substances have been found effective against the San Jose scale, but the kerosene mixtures and emulsions were abandoned by me in December, 1901, because of serious damage done to trees with these insecticides in 1900 by one of my spraying parties, working under the immediate personal charge of my most experienced operator.† Crude petroleum, much used in some other states, has been little used at any time in Illinois, and observations made by one of my assistants in 1902 in the Catawba Island district in northern Ohio, where it had been extensively applied by orchardists, were so discouraging that I have made but a single experiment with it.‡

After the passage of the Illinois inspection law in 1899 it became my duty to treat, free of expense to the owner, all orchards infested by the San Jose scale which there was good reason to believe had become so infested before the passage of that act. As it has now become virtually impossible to trace existing infestations to so remote a beginning, this feature of our law has become practically inoperative, and the owner is required to treat infested trees on his own account. This fact has made it important that every effort should be made to distinguish, among the various available insecticides, those which are at the same time effective, cheap, and convenient of preparation and application, especially as several commercial compounds of lime and sulphur, and others with a kerosene basis, are being extensively advertised and offered in condition for immedi-

*Twenty-second Rep. State Ent. Ill., pp. 56-57, 89-90; Bull. 80, Ill. Agr. Exper. Station, pp. 492-493.

†Twenty-second Rep. State Ent. pp. 48-50.

‡*Ibid.*, pp. 93-95.

ate application when diluted. I consequently, last winter, instructed Mr. E. P. Taylor, the assistant in charge of orchard inspection and insecticide operations, to carry on a series of experiments in a carefully chosen orchard, intended to test a number of these insecticides under identical conditions and in a way to enable us to give the results in the exact form of percentages of benefit for each.

For this purpose, control was obtained of two small orchards near Richview, Ill., both belonging to Mr. Edward Tucker, one containing 780 apple- and peach-trees badly infested in the main, and the other, 680 peach-trees infested throughout but much less heavily so. These orchards were divided into plots of varying size, those intended for the more important insecticides containing from 47 to 141 trees each. Minor experiments were made on smaller lots, of from 3 to 33 trees, and single trees here and there were also used for a few preliminary tests.

Insecticides were applied, partly early in January, from the 3d to the 10th, and partly from the 21st to the 24th of March, 1905. Twenty-seven kinds and forms of insecticides were used in all, of which seventeen were various compounds of sulphur and lime, six were kerosene preparations, three were soap solutions, and one was a simple alkali. The results were tested by three critical examinations, one made January 3 and 4, a second during the last days of May, and the last September 5 to 8. It is of course impossible to get an accurate idea of the effects of the treatment by comparing the ratio of living to dead at the time of the treatment with the corresponding ratio at a considerable interval thereafter, unless the scales remain attached to the tree after death; and that they gradually disappear, especially after a lime and sulphur treatment, was shown by observations reported by me in 1902.*

SYSTEM OF INSPECTION.

The choice of a system of inspection by which the condition of trees treated with various insecticides could be compared with their condition before treatment, and with that of other trees not treated but reserved as checks, was a difficult and perplexing matter. At first I was disposed to depend mainly on counts of dead and living scales from various parts of carefully selected trees, from which average ratios of dead to living, before and after treatment, might be computed, but such comparisons rapidly become misleading as the scales killed by the spray disappear under exposure to the weather. Comparisons of the results of treatment with different insecticides can not be reliable if based on counts of living and dead,

*Bull. Ill. Agr. Exper. Station, No. 71, p. 243.

because the scales killed by one insecticide may remain longer attached to the bark than those killed by another, and there is abundant evidence that this is often the case. It is furthermore practically impossible to make sure that a tree selected for a scale-count is a fair average of its plot with respect to the degree of its infestation, and scarcely less difficult to make sure that the parts of its infested surface selected for counting are a fair average for the tree. For these reasons the counting method was abandoned, in the main, and I have relied instead upon a careful estimate of degrees of infestation for each tree of both check and experimental plots, these estimates being recorded in figures ranging from 1 to 6. From these the average degrees of infestation for the trees of each plot were figured, and these averages were compared with each other in a way to show numerically the effect of the treatment in a reduction of the average amount of infestation.

CONDITIONS NECESSARY TO EXACT EXPERIMENT.

In order to an estimate of the precise value of the results here reported, it will be helpful to review the conditions necessary to an entirely satisfactory experiment of this description. In the first place one should have at his command an orchard of considerable size, either all of one variety or with the separate varieties planted in complete and continuous rows all running in one direction. This should be divided across its whole width, and across the variety rows, into strips of five rows each if moderately infested by the San Jose scale, and into seven to ten rows if heavily infested, each strip receiving a different treatment except that occasionally strips should be left untreated as checks. To avoid the mutual influence of check and experimental plots upon each other, which may extend from one to three rows in each direction across the boundary, only the interior rows of each strip should be used for comparison. Experimental trees near the borders of the check strip are likely to receive young scales from the latter in larger number than they lose, if the experimental treatment has had any marked effect, and the reverse is of course true of the marginal rows of the check. This is not a theoretical supposition merely, but is shown by our previous experience, and by some of the averages to be reported farther on. As the check plots will act as centers of general dispersal of the scale insects during the whole of the following season, there should be no more of them than are clearly necessary. One at each end of the orchard will usually be enough.

The trees of the interior rows of each strip should be graded very

carefully, one by one, as to the degree of their infestation, using, for convenience, a scale of ten degrees. One such grading should be made and recorded at the time the trees are sprayed, another about the last of May, just as the young are beginning to appear, and a third at the end of fall, when multiplication of the scales has virtually ceased for the season. All the grading should be done by one person, or by two persons independently, their estimates being averaged, and the person grading the infestation should not know the particulars of the experimental treatment.

A comparison of the average degrees of infestation of the checks when the spray is applied, and again in May, will show the extent to which the scales may have died during the interval, under the effects of weather or from other causes, and a comparison of the check and experimental plots, respectively, in May, will show the immediate effect of the insecticide. A similar comparison of these two kinds of plots, made at the end of the season of multiplication, will show the ultimate effect of the treatment at the end of the year.

ORIGINAL PURPOSE OF OPERATIONS.

Our own operations were originally planned with special reference to the comparative values of modifications of the lime and sulphur mixtures proposed by various entomologists, and also as a preliminary test of the efficiency of soluble petroleum, lime and sulphur solutions, and other ready-made commercial products frequently offered for sale. Reports made by my field parties of the partial failure of midwinter sprayings with the lime and sulphur washes led me also to provide for a careful test of the final effect of sprays applied in January as compared with those applied in March.

MOST GENERAL RESULTS.

The main general outcome of these experiments was to establish still more firmly the lime and sulphur washes as superior, on the whole, to all the other mixtures tested, and to show that January applications of these preparations have scarcely more than half the final effect of applications made in March. Among the lime and sulphur mixtures, those made without salt or blue vitriol seemed clearly more efficient, as insecticides, than the older forms containing those substances, and the solutions made with soda, without boiling, were the least efficient of all.

THE LIME AND SULPHUR MIXTURES.

Seventeen preparations with a lime and sulphur basis were used in these experiments. They included various forms of the "California wash" and the "Oregon wash," and mixtures of lime and sulphur without the salt necessary to the former or the blue vitriol necessary to the latter. These preparations varied in the kind of lime used in making them, in the proportions of the various ingredients, and in the length of time during which the mixtures were boiled to procure the solution. Two compounds purporting to be ready-made solutions of lime and sulphur were used, known respectively as "Calcothion" and "Con Sol."

Major Experiments.—Eleven of these experiments, in which more than 50 trees were treated, will be reported first, in the order of their final effectiveness.

1. This was a lime and sulphur wash made of 15 pounds of Marblehead lump-lime and an equal weight of sulphur to 50 gallons of water. The sulphur was first put into 12 gallons of water nearly at the boiling point, after being mixed with enough water to form a thin paste. The lime was then added and the mixture was boiled for 40 minutes with the necessary stirring. The whole was strained into a 50-gallon tank which was then filled with water.

Fifty-one trees were treated March 22, 1905, in the less-infested orchard (Orchard II.), at a sufficient distance from the check strip to prevent any possible spread of the young scales to the experimental plot. The trees on this plot were compared September 10 with those in the two central rows of the check plot—which was six rows wide—both being carefully graded as to degree of infestation according to the system already described. The check trees averaged at this time 5.6 degrees of infestation, estimated on a scale of six degrees. Those of the experimental plot, on the other hand, averaged 1.2 degrees—a difference of 4.4 degrees in favor of the experimental plot, or a ratio of benefit of 79 per cent.* In other words, the number of living San Jose scales on this experimental plot was virtually one fifth that which would have been present September 10 if no treatment had been applied.

Finally, if we compare the condition of this experimental plot September 10 with the condition of the same plot January 3, when the trees were first inspected, we find that the September infestation averages just one half that of January.

2. This was also a lime and sulphur mixture, differing from the

*To ascertain this ratio, the figures denoting the infestation of the experimental plot are subtracted from those of the check plot, giving 4.4 per cent. as the difference, and this divided by 5.6, the measure of infestation of the check trees, gives 79 per cent.

preceding especially in the fact that 21 pounds of lime and 18 pounds of sulphur were used to 50 gallons of water. The method of preparation was virtually the same.

Sixty-six trees, in four rows running across the end of the less-infested orchard, II., were treated March 22 with one hundred gallons of the spray. At a general inspection made May 27, this plot was reported as in favorable condition, with very few living scales, and none of them young. Examined September 10, the average infestation was figured at 1.36 degrees, which, compared with the infestation of the two central rows of the check plot, gives a benefit of 76 per cent. as a consequence of the treatment. Compared with its own average infestation of the preceding January, we find this plot improved about 44 per cent.; that is to say, the degree of September infestation is approximately 56 per cent. that of the preceding January. In the check plot, with which this is to be compared, the September infestation was nearly two and a half times that of January.

3. This is a simple lime and sulphur mixture like No. 1 of this series, the ingredients being in the same proportions of 15 pounds each of lime and sulphur to 50 gallons of water, and differing merely in the method of preparation. In this, the lime was first slaked in 10 gallons of water where 50 gallons of the spray were to be prepared, the sulphur was then stirred in dry, and the whole was cooked from 30 to 40 minutes.

One hundred and one trees of Orchard II. were sprayed March 22 with one hundred and forty gallons of the solution. As this plot of six rows, running the whole width of the orchard, lay immediately beside the check, the average September infestation of the two rows adjoining the check was notably greater than that of the remaining four rows. For the first two rows it averaged 1.9 degrees, and for the remaining four rows, 1.44—an excess of 32 per cent. of infestation, apparently due to the proximity of the check and the consequent spread of the young from those heavily infested trees. On this account the two inner rows of 17 trees each were rejected, and the four rows remaining were compared with the two central rows of the check plot itself.

Comparing the 1.44 degrees of infestation of the experimental trees with the 5.6 of the rows used as checks, we have a benefit of 74 per cent. resulting from the treatment. Or, if we choose to compare the September condition of the plot with that of January—again omitting the rows nearest the check—we find a difference of 38 per cent. in favor of the September condition.

4. This was the so-called "California wash," containing 15 pounds each of lime, sulphur, and salt, to 50 gallons of water.

Thirty pounds of sulphur was first stirred into 20 gallons of boiling water, and 30 pounds of lime was added. The mixture was then boiled for thirty minutes, with constant stirring, after which 30 pounds of salt was added and the boiling was continued for 15 minutes more. The mixture was then diluted with water to form one hundred gallons, and applied March 21 to 66 trees of Orchard II., standing in four rows at a considerable distance from the check.

Examined May 29, this plot was reported to be in excellent condition, with but few living old scales and scarcely any young. Of 100 scales taken at random, 15 were alive—a ratio which, however, would have but little significance, two months having elapsed since the trees were sprayed. On a visit to these trees made September 10, this plot showed an average of 1.8 degrees of infestation, corresponding to a benefit of 68 per cent. as compared with the condition of the check at the time. If the comparison be made with the January condition of the same plot, the September condition shows a gain of 37 per cent.

5. This, like the preceding number, is a "California wash," but with 21 pounds of lime, 18 pounds of sulphur, and 5 pounds of salt, to 50 gallons of water. It was prepared, like the preceding mixture, by pouring the sulphur into the water first, and following with the lime.

It was applied March 22 to 49 trees standing in three rows of Orchard II., seven rows intervening between this plot and the check. May 29, scattering full-grown females were seen, but young were extremely few. Only 7 were found on 5 trees. The bark was still covered with an even whitish coat at this date—two months after spraying. Of 148 scales examined, 20 were alive. On September 10 the average infestation was estimated at 1.9 degrees, which, compared with the check rows, gave a benefit ratio of 67 per cent. That is, the scales alive on these trees were approximately one third the number which the trees would have borne if they had not been treated the preceding March. Compared with the January estimate, the September infestation was about 25 per cent. less. In other words, the effect of the spray up to this time had been to counterbalance the increase of the scale by multiplication, and to reduce the original number by one fourth.

6. The usual "California wash," made with 15 pounds each of lime, sulphur, and salt, to 50 gallons of water, the lime being first slaked, and the sulphur added in the form of a paste. The mixture was then boiled for 30 minutes, and the salt was added and the whole boiled 15 minutes more.

Sixty-eight trees of Orchard II. were treated March 21. They

were in four rows running across the orchard near one end, and far removed from the check. May 29 a few old living scales were found on half a dozen trees, but no young, either crawling or newly set. The bark of some of these trees was still covered with innumerable dead scales. September 10 the scales remaining had multiplied somewhat, giving an average infestation of 2. degrees, and showing a benefit of 64 per cent. Compared with the condition of the trees in January, at which time the infestation was estimated at 33 per cent. per tree, the September condition showed an improvement of 38 per cent.

7. These trees, unlike all the preceding, were in the orchard originally the worse infested of the two (Orchard I.), its check plot averaging, in January, 3.3 degrees of infestation when that of the other orchard (II.) averaged 2.2 degrees. At the time of the September inspection, however, this difference had more than disappeared, the infestation of these two orchards being now 4.94 for Orchard I. and 5.36 for Orchard II. That is to say, the infestation of the orchard worse infested in January had increased by 49 per cent. while that of the less-infested had increased by 145 per cent. The reasons for this difference were not clear. The September infestation of the check plot in Orchard I. was practically uniform, showing no invasion from the adjoining plots, and I have used, for comparison, the averages for the whole of it instead of those for the two central rows only, as in Orchard II.

This experiment was a January treatment of 141 trees, some peach and some apple, with the "Oregon wash" made of 15 pounds each of lime and sulphur, and $1\frac{1}{2}$ pounds of blue vitriol, to 50 gallons of water. Two hundred gallons of the wash were used January 3 and twelve gallons more the following day. The temperature of January 3 was but a few degrees from freezing, part of the time above and part of the time below. The ground was covered with snow, and light winds blew from the north and northwest. January 4 the temperature fell nearly to zero, and the wind shifted to the south.

The solution was prepared by the process commonly used in all our recent orchard work, the lime being first placed in water which had been heated to the boiling point, and the sulphur paste introduced while the lime was slaking. The mixture was boiled for 30 to 40 minutes, and the blue vitriol, previously dissolved, was added and the whole boiled for 5 minutes more. All of the trees were thoroughly sprayed, and but few tips of twigs or patches of bark could be found not covered by the residue after the fluid had

evaporated. During the colder part of these days the spray froze as soon as it touched the bark.

May 26, 964 scales were examined, of which 773 were dead, and 191, or 20 per cent., alive. May 29 a general inspection of this plot showed many living scales, young and old, both decidedly more abundant on the apple than on the peach. Fifty young, for example, were found in one square inch of the under surface of a twig two inches in diameter, and on another equal area 110 were counted. Traces of the winter spray were still visible on the trees. September 5 the average infestation was estimated at 2.4 degrees, which, compared with the 4.94 of the check plot for this orchard, gave a benefit ratio of 51 per cent. If the September condition of these trees is compared with that of January, a gain of 23 per cent. is found.

8. This is a companion experiment to No. 6, the same preparation being used, in the previous case in March and in this case in January. It was the usual "California wash" of 15 pounds each of lime, sulphur, and salt, to 50 gallons of water. It was sprayed January 10 upon three rows of peaches, 47 trees in all, in Orchard II.—a plot immediately beside No. 6. The temperature ranged from 10° to 12° above zero, and snow was falling, with a northeast wind. The spray froze as it struck the trees.

At the inspection of the 29th of May this plot was reported as in very unfavorable condition, many young scales being found on 4 trees examined. September 10 the infestation of this plot averaged 3.1 degrees—to be compared with 5.6 of the check plot of its orchard. This gives a benefit of 45 per cent. as compared with the September check, or of 12.5 per cent. if compared with its own January condition.

9. This is an experiment with the "Oregon wash," 20 pounds of lime, 15 pounds of sulphur, and 1½ pounds of blue vitriol, to 50 gallons of water. It was applied to a plot of eight rows in Orchard I. containing 126 trees, only five rows of which, containing 78 trees, were used for comparison, owing to an apparent contamination of three rows from the check plot adjoining. These trees were sprayed January 3 to 5, the temperature ranging from 28° to 36°. Two hundred and sixty-two gallons were used, the most of it January 4.

One thousand and ten scales taken at random from 12 trees were examined in this orchard May 27, and 26 per cent. were found alive. Generally speaking, however, the condition of the orchard was reported as extremely favorable. Most of the insects found were on the higher twigs, which were less heavily coated with the residue

of the spray than were the larger branches and the trunk, and the greater part of the living scales were found on such twigs. They were, as before, more abundant on the apple than on the peach. September 5 the average infestation of the 78 trees available for comparison was figured at 2.9 degrees, which, compared with the 4.9 of the check plot, gives a benefit of 42 per cent. from this January treatment with the "Oregon wash." As compared with its own January condition, this plot had been improved by 12 per cent.

10. A January spray of a lime and sulphur mixture made with soda—30 pounds of lime, 15 of sulphur, and 5 of soda, to 50 gallons of water. The mixture was prepared January 4 as follows:

Thirty pounds of Marblehead lime was slaked in 12 gallons of water, the sulphur being added in the form of a paste during the slaking process. The soda was added in three lots, the first about 5 minutes after the lime began to slake, and the others at intervals of 2 or 3 minutes. The mixture was then stirred for 10 minutes, diluted with cold water to make 50 gallons, no boiling being necessary, and applied to 127 trees in Orchard I.—a plot of eight rows immediately beside the check. The temperature was a little above or a little below freezing, a strong wind blowing from the south. There was no appearance of any increased infestation on the side nearest the check plot, and the averages for all these rows are consequently used for comparison.

May 27, scales were quite numerous on this plot, including both well-grown females and some young. Of 676 examined, 30 per cent. were found alive. On the check plot at the same time, of 1200 scales examined, 39 per cent. were alive. September 5, when the infestation of this plot was finally graded, it was found to average 3.37 degrees, less by some 23 per cent. than the infestation of the check plot in this orchard. Compared with its own January condition, the September infestation was estimated at practically 15 per cent. less.

11. This, like the preceding, is a lime, sulphur, and soda mixture, differing in the smaller proportions of lime and sulphur and in the greater amount of soda. Sixteen pounds of lime and 8 each of sulphur and soda were used to 50 gallons of water. In the preparation of this solution 8 pounds of sulphur paste was put into a few gallons of boiling-hot water, 8 pounds of caustic soda was added to this and stirred until the sulphur was dissolved, and 16 pounds of lump-lime was then put in and stirred until completely slaked. The entire process required about 15 minutes' work.

The spray was applied January 5 in Orchard I. to 124 trees, about equally peach and apple, the temperature varying from 32° to

54° at different times of the day. The plot of eight rows was at the end of the orchard and consequently well removed from the check.

May 27, these trees were found unusually infested as compared with others treated at the time. Of 575 scales examined, 159 were living—a ratio of 28 per cent. At the fall inspection, September 5, the average infestation of this plot was rated at 3.43; giving a benefit of 19 per cent. for the treatment if compared with the check, or about 12 per cent. if compared with its own January condition.

The principal data of the foregoing discussion may be conveniently summarized, for further consideration, in the first of the following tables.

I. TABLE OF EXPERIMENTS WITH LIME AND SULPHUR PREPARATIONS
ON PLOTS OF 47 TO 141 TREES.

(Arranged in order of benefit from treatment.)

No. of Exper.	Insecticide	Or- chard	Trees	Treated	Sept. Infes- tation Degrees	Sept. Bene- fit per cent.	Cost per 100 Gals.
	Check Plot	I	126		4.94		
	Check Rows	II	34		5.6		
1	Lime and Sulphur* 15 L., 15 S., 50 W.	"	51	Mar. 22	1.2	79	\$.84
2	Lime and Sulphur 21 L., 18 S., 50 W.	"	66	" "	1.36	76	1.03
3	Lime and Sulphur† 15 L., 15 S., 50 W.	"	67	" "	1.44	74	.84
4	California wash* 15 L., 15 S., 15 salt, 50 W.	"	66	" 21	1.8	68	.94
5	California wash 21 L., 18 S., 5 salt, 50 W.	"	49	" 22	1.9	67	1.07
6	California wash† 15 L., 15 S., 15 salt, 50 W.	"	68	" 21	2.	64	.94
7	Oregon wash 15 L., 15 S., 1.5 B. V., 50 W.	I	141	Jan. 3	2.4	51	1.
8	California wash 15 L., 15 S., 15 salt, 50 W.	II	47	" 10	3.1	45	.94
9	Oregon wash 20 L., 15 S., 1.5 B. V., 50 W.	I	78	Jan. 3-5	2.9	42	1.07
10	Lime, Sulphur and Soda 30 L., 15 S., 5 soda, 50 W.	"	127	" 4	3.37	23	1.44
11	Lime, Sulphur and Soda 16 L., 8 S., 8 soda, 50 W.	"	124	" 5	3.43	19	1.24

*Sulphur put in first, lime added.

†Lime first, sulphur added.

RECAPITULATION.

	Simple lime & sulphur	II	184	March	1.33	76
	California washes	"	183	"	1.9	65
	Oregon & California washes	I & II	266	January	2.8	46
6	California wash	II	68	March	2.	64
8	" "	"	47	January	3.1	45
	Lime, sulphur, & soda	I	251	"	3.4	21

II. TABLE OF EXPERIMENTS WITH LIME AND SULPHUR PREPARATIONS ON PLOTS OF 5 TO 12 TREES.

No. of Exper.	Insecticide	Orchard	Trees	Treated	Sept. Infestation Degrees	Sept. Benefit per cent.	Cost per 100 Gals.
12	Oregon wash with Del. limoid. 20 L., 15 S., 1.5 B.V., 50 W.	I	11	Mar. 24	1.91	61	\$1.07
13	Oregon wash with Wis. limate. 20 L., 15 S., 1.5 B.V., 50 W.	"	12	" 23	2.08	58	1.07
14	Oregon wash with hydrated lime No. 1. 20 L., 15 S., 1.5 B.V., 50 W.	"	11	" 24	2.18	56	1.07
15	Oregon wash with hydrated lime No. 2. 20 L., 15 S., 1.5 B.V., 50 W.	"	11	" "	2.18	56	1.07
16	Calcothion.	"	5	" 22	2.3	55	5.
17	Con Sol. 1 part to 40.	"	9	" "	4.21	15	2.40

III. MISCELLANEOUS EXPERIMENTS.

No. of Exper.	Insecticide	Orchard	Trees	Treated	Sept. Infestation Degrees	Sept. Benefit per cent.	Cost per 100 Gals.
18	Scalecide	I	31	Mar. 24	2.57	47	\$2.50
19	Whale-oil soap 2 lbs. to the gallon	II	117	" "	1.9	65	8.
20	Tak-a-nap soap 1 lb. to the gallon	I	8	" "		15	5.

GENERAL RESULTS OF THE FOREGOING ELEVEN EXPERIMENTS.

An examination of the column of the preceding table showing percentages of "September benefit" for the various kinds of treatment enables us to divide at once the series of experiments into four groups—three of three experiments each, and one of two. The first six experiments were all made in the same orchard, and all in March. It is especially interesting to see that the first three, in which the insecticide was a simple lime and sulphur solution without salt or blue vitriol, show ratios of 74 to 79 per cent. of benefit, with an average of 76.3, while the next three experiments, all made with the "California wash," the composition being the same as that of the preceding three except that salt was added, give ratios of benefit ranging from 64 to 68 per cent., with an average of 65.

These experiments strongly indicate, if they do not substantially prove, that the addition of salt to the lime and sulphur is a detriment rather than a benefit, since a difference of 17 per cent., or more than one sixth, in the ratios of apparent benefit, under conditions otherwise so uniform, can scarcely be accounted for in any other way.

The next group of experiments, 7 to 9 of our series, when contrasted with Experiments 4 to 6, show a difference in final effect of spring and midwinter sprayings. The average benefit of the "California wash" applied to 187 trees in March was 65 per cent., while that of the Oregon and California washes applied to 320 trees in January was 46 per cent.—a difference of 41 per cent. in favor of the spring treatment. The January group of three experiments does not compare exactly with the March group of three, since two of the former were made on a different orchard from the latter, and were made with the "Oregon wash" instead of the "California wash." If, however, Experiment 8 be compared with Experiment 6, in which all the conditions were identical except the time of spraying, we get the same difference of ratios of benefit as before—45 per cent. for the January treatment and 64 per cent. for the March treatment.

Furthermore, the last two experiments, 10 and 11 of our series, contrast still more strongly with the three preceding, giving but 19 and 23 per cents of benefit, with an average of 21 per cent. as compared with 46 per cent. for the preceding group. This difference of more than 100 per cent. can be accounted for only on the supposition that the cold solution of lime and sulphur made with soda was far less efficient as an insecticide than the ordinary form of Oregon and California washes made by boiling.

One additional inference may be drawn from a comparison of Experiments 1 and 4 on the one hand with 3 and 6 on the other. In each of the former pair the lime was slaked in water in which the sulphur had been first stirred up. In each of the latter pair the lime was put in first, and the sulphur was added during the slaking process. That there is an apparent advantage in the first method of preparation is shown by the difference of 5 degrees of benefit between Experiments 1 and 3, and 4 degrees of benefit between Experiments 4 and 6. It thus appears that solutions made by stirring the sulphur into the hot water first and adding the lime to this mixture, are more efficient than if the order of procedure is reversed.

It follows from this discussion, as a general conclusion, that simple solutions of lime and sulphur made by boiling, without salt or blue vitriol, the sulphur being added to the water first, had much the best insecticide effect in these orchards; that the March spraying was nearly twice as effective as the January spraying; and that the soda solutions of lime and sulphur made without heat had a final efficiency less than half that of the boiled solutions applied at the same time.

Minor Experiments.—Six experiments with other lime and sulphur mixtures were made on too small a scale to compare with the eleven preceding, but with results which seem to me worthy of record, particularly as they are fairly uniform for this group of insecticides notwithstanding the small number of trees used in each experiment.

From 5 to 12 trees were sprayed with various forms of the "Oregon wash," with "Calcothion," and with "Con Sol," all in March from the 22d to the 24th, and all in Orchard II. Four of the insecticides used were forms of the "Oregon wash" made with different brands of hydrated lime instead of ordinary lump-lime from the kiln. In all cases 20 pounds of the lime, 15 pounds of sulphur, and 1½ pounds of blue vitriol were used to 50 gallons of water, the only difference being in respect to the kind of lime, the so-called Wisconsin "Limite" being used in one, the Marblehead hydrated lime in two others, and the Delaware "Limoid" in the fourth. These were applied in each case to 11 or 12 trees, and the effect was ascertained by the inspection method used in the larger experiments.

The resulting benefits ranged from 56 to 61 per cent., as tested by the September inspection, using the September condition of the check plot of Orchard II. as a basis of comparison. These mixtures, with their average benefit of 58 per cent., were apparently less efficient than the California washes used at the same time, which give a benefit of 65 per cent. The "Calcothion," applied cold without di-

lution, as it was received from the manufacturers, was used on only 5 trees, with a ratio of September benefit figured at 55 per cent.—substantially the same as that of the Oregon washes just referred to. “Con Sol,” diluted with water at the rate of 1 to 40, and applied cold to 9 trees, gave a ratio of only 15 per cent. of benefit. The Oregon washes cost at the rate of \$1.07 per hundred gallons for materials: “Con Sol,” \$2.40; and “Calcothion,” \$5.

It may be provisionally inferred from these small experiments that neither of these two compounds has any advantage over the better-known washes except in point of convenience, and this must be paid for by a considerably higher cost than that of the lime and sulphur mixtures—more than twice as great for “Con Sol,” and nearly five times as great for “Calcothion.”

MISCELLANEOUS ADDITIONAL INSECTICIDES.

Only one of the kerosene insecticides was tried on a number of trees sufficient to give any permanent value to the experiment. The soluble petroleum compound known as “Scalecide,” applied March 24 in a 5 per cent. mixture with water to 31 trees in Orchard I., showed a September infestation of 2.6 degrees, equivalent to a benefit of 47 per cent.—decidedly less than that of any of the lime and sulphur washes used in March, as shown by Table I., and considerably less than that of the Oregon washes of Table II. It seems to belong, in insecticidal effect, with the Oregon and California washes as applied in January, its 47 per cent. of benefit being substantially the same as the 46 per cent. of the latter treatment. Its cost was \$2.50 per hundred gallons—essentially the same as “Con Sol”—and its benefit was three times as great. It was apparently the best of the ready-made insecticides tested by us last year.

A kerosene preparation known and sold as “Frutolin” was tried March 24 on 3 trees, and several variations of a 20 per cent. kerosene mixture made with water and hydrated lime in lieu of soap solution were applied on the same day to 5 more trees, all in Orchard I. The results were essentially the same with all these mixtures, so far as one can judge from these small experiments. The trees treated averaged 4 degrees of infestation September 10, giving a benefit ratio of 19 per cent. as compared with the check of their orchard. The cost of the “Frutolin” mixture was \$25.10 per hundred gallons, and that of the so-called emulsions made with kerosene and lime was \$1.07.

Two simple soap solutions were used, whale-oil soap on 117 trees, and “Tak-a-nap” soap on 8 trees, the former in Orchard II.

and the latter in Orchard I. The whale-oil soap was used March 23 and 24 in the ordinary ratio of 2 pounds to the gallon of water on a plot immediately beside the check plot of its orchard. As the row adjacent to the check showed much the highest infestation of any one of the seven, it has been thrown out in the comparison.

September 10 the infestation of this plot was reckoned at 1.9 degrees, which, compared with that of the check plot at the same time, gives a benefit ratio of 65 per cent.—making this solution virtually the equivalent of the California washes made with salt, as shown in Table I. Its cost, \$8 per hundred gallons of the solution—nearly eight times that of the California washes,—is the most serious obstacle to its general use. Except for its occasional destruction of blossom buds of the peach and other especially sensitive fruits, it would still remain the most desirable for use on a small scale. For the apple orchard, if the difference in expense is not worth considering, it is to be recommended as among those next in efficiency to the simple lime and sulphur washes.

“Tak-a-nap” soap dissolved in cold water at the rate of one pound to the gallon, and applied March 24 to 8 trees in Orchard I., gave an apparent September benefit of 15 per cent. The cost is \$5 for one hundred gallons.

A caustic-soda solution made with water at the rate of 1 pound to 6 gallons and applied to 3 trees March 24 produced no perceptible effect, these trees being, in fact, worse infested in September than they were in January, and even worse than were the trees of the check plot at the September inspection.

Mention may also be made of Bowker's Tree Soap, used on only a single tree, but there apparently with very good effect. It was applied March 24 to a badly infested tree in Orchard I. at the rate of 2 pounds of soap to a gallon of warm water.

At the time of the May inspection 100 scales from this tree were counted, all of which were dead, and Mr. Taylor remarks that he could not find a scale on this tree alive, though he scraped and examined most of the twigs to their tips. By September, however, this tree was moderately infested, possibly by invasion from adjacent trees which had been treated with kerosene emulsion.

This soap costs $7\frac{1}{2}$ cents per pound in 100-pound kegs, bringing the cost of the spray to \$15 per hundred gallons.

COST OF MATERIALS .

The cost of all the materials contained in the various insecticides used in these experiments is shown in the last column of the tabular

summaries, with the exception of those used in certain minor experiments, which have been separately given. This cost, stated in terms of one hundred gallons of the spray diluted and otherwise made ready for actual distribution, is based on the following rates for materials, which are those actually paid by us, or, in a few minor cases, those furnished us by the manufacturers. None of these prices includes freight.

- Lime. 90 cents per bbl. of 196 lbs.
- Sulphur. \$2.30 per cwt., bought in ton lots.
- Salt. 33 cents per cwt., by the bbl.
- Blue vitriol. \$6 per cwt.
- Caustic soda. \$4.50 per cwt., in 10-lb. cans.
- Whale-oil soap. 4 cents per lb., by the bbl.
- Tak-a-nap soap. 5 cents per lb., in 40-lb. packages.
- Kerosene. 12½ cents per gal., by the bbl.
- Marblehead hydrated lime No. 1. 50 cents per cwt.
- “ “ “ “ 2. 50 cents per cwt.
- Wisconsin limate. 50 cents per cwt.
- Delaware limoid. Highest grade, \$5. per bbl. of 200 lbs.; cheaper grade, \$2.50 per bbl., or \$14. per ton.
- Calcothion. 5 cents per gal., if bought by the bbl.
- Con Sol. \$1. a gal.
- Frutolin. 66 cents per liter (1.06 quarts) in cases, each containing a dozen liter cans.
- Scalecide. 50 cents per gal., in 50-gal. bbls.

The cheapest of these washes, counting cost of materials only, is, fortunately, the one found most efficient in these experiments, namely, the simple lime and sulphur wash in the ratio of 15, 15, 50, and costing 84 cents per 100 gallons when ready for spraying. The next in order is the common “California wash” of lime, sulphur, and salt (15, 15, 15, 50), costing 94 cents per hundred gallons. The “Oregon wash” made by the old formula still in most general use, and containing 15 pounds of lime, 15 pounds of sulphur, and 1½ pounds of blue vitriol to 50 gallons of water, costs \$1 per hundred gallons; and the simple lime and sulphur mixture with 21 pounds of lime and 18 pounds of sulphur to 50 gallons, costs \$1.03. The “Oregon wash” with the lime (of whatever form) increased to 20 pounds, amounts to \$1.07 per hundred gallons; and the lime and soda washes, from \$1.24 to \$1.44, dependent upon the proportions of the ingredients as given in Table I., Experiments 10 and 11.

The next in order of cost is “Con Sol,” at \$2.40 per hundred gallons, 1 part of the insecticide to 40 of water; and then “Scalecide,” \$2.50 per hundred gallons, when used in a 5 per cent. solution. The kerosene emulsions made with hydrated lime and diluted to contain

20 per cent. of kerosene, cost \$3.62 for a hundred gallons of the diluted mixture. "Tak-a-nap" soap, a pound to the gallon, costs \$5 a hundred gallons, and the ordinary solution of whale-oil soap, \$8 for the same amount. "Frutolin" costs \$25.10 per hundred gallons when diluted with 9 parts of water to 1 of "Frutolin," as advised by the manufacturers.

GENERAL SUMMARY.

1. The cheapest and most efficient of the eleven insecticide mixtures thoroughly tested against the San Jose scale were the simple lime and sulphur mixtures (without salt or blue vitriol) dissolved by boiling together. They cost, for materials, from 84 cents to \$1.03 per hundred gallons of the fluid spray, varying according to the proportions of the chemicals used. Infested trees treated with these solutions in March, bore about one fifth as many scales the following September as companion trees not treated.

2. The next in value was the "California wash" made with lime, sulphur, and salt, at an expense of 94 cents to \$1.07 per hundred gallons, and the "Oregon wash" of lime, sulphur, and blue vitriol, costing virtually the same.

3. There was a marked and very important difference in the final effect of these washes and mixtures, dependent upon the time of their application, the midwinter treatment yielding a result far inferior to that of early spring.

4. The cold solution of lime and sulphur made with soda was found less than one third as effective as the washes dissolved by boiling. Its materials were also somewhat more costly, varying, according to the proportions of the ingredients, from \$1.24 to \$1.44 per hundred gallons.

5. The petroleum preparation known as "Scalecide," which has the advantage that it may be prepared for use by simply diluting with water, was found somewhat less efficient than the lime and sulphur mixtures, and cost about $2\frac{1}{2}$ times as much as the raw materials of those preparations.

6. Whale-oil soap compared very well with the "California wash," but at a cost approximately eight times as great.

7. Less confident statements may be made with reference to Oregon washes made with hydrated lime, and to the commercial insecticides known as "Con Sol" and "Calcothion," experiments with these substances having been made on too small a scale to warrant final conclusions. They strongly indicate, however, that, with the exception of "Con Sol," these mixtures have an insecticide value some-

what less than that of the ordinary "Oregon wash." "Calcothion" is applied as received, without either additional preparation or dilution. It has the disadvantage of a high cost, amounting to \$5 per hundred gallons.

8. Minor experiments with several additional insecticides are briefly described on pages 72 and 73.

9. The expense of preparation of the mixtures to be dissolved by boiling is so variable, according to the amount to be used, the supply of available labor, and the kind and cost of fuel, that no attempt has been made to estimate it. For all the lime and sulphur solutions except those made with soda, and for whale-oil soap, it amounts virtually to the cost of boiling successive quantities of fifty gallons of water, each for 30 to 45 minutes.

SPRAYING APPLES FOR THE PLUM-CURCULIO.

It has been known for more than a hundred years that the apple was subject to injury by the plum-curculio, but as this injury has been commonly reckoned less important than that done by the codling-moth, the matter has received, of late, comparatively little attention until within the last six or seven years. Since the discrimination of different market grades of apples has been generally introduced—a grading based not only upon size and soundness, but also upon superficial appearance—the slight surface injuries done by the new generation of the plum-curculio, both in laying the eggs and in feeding on the fruit, have acquired a great importance. The consequence of a noticeable injury of this sort, although affecting but little, and in many cases scarcely at all, the edible quality of the apple so injured, is to reduce its selling value from No. 1 grade to No. 2, the actual profits of the crop disappearing in this process. These facts having been repeatedly brought to my knowledge by Illinois horticulturists, I undertook to work out the causes of these surface blemishes in general, and to demonstrate more accurately than has hitherto been done means of preventing them by a destruction of the curculios themselves. Indeed, the importance of this investigation has grown upon me as it has become evident that these small superficial injuries very often give entrance through the skin of the apple to bacteria and to fungus spores of various kinds, causing rots and blights of the fruit which might be largely prevented by a timely destruction of the insects.

SOME EARLIER EXPERIMENTS.

The first exact experiments with insecticides for the protection of apples against the plum-curculio were those made at my office in 1885, on a small orchard hired for the purpose near Urbana, Ill., the results of which were published in one of my reports*, and in the Transactions of the Illinois State Horticultural Society for that year. In this experiment, which was made primarily to test insecticide measures for the destruction of the codling-moth, the effect on

*Misc. Essays on Econom. Ent., 1886, pp. 26-45.

curculio injuries was likewise ascertained. Eight trees were used, 4 of them being sprayed and 4 reserved as checks. Two of the trees were treated with Paris green, 1 with London purple, and 1 with lime. All applications were made eight times, beginning the 9th of June and continuing until September 3.

All the apples borne by these trees, 16,529 in number, both those which fell and those which remained on the tree, were examined one by one, and the results were tabulated for comparison. Although this was my first work with orchard insecticides, and the application was doubtless not made as thoroughly as would now be done, the general result of the work with Paris green was to save uninjured on the trees 56 per cent. of the apples which would otherwise have been injured by curculios—a percentage less than was to have been expected in orchard practice because, as noted at the time, there were other bearing trees in the orchard, from which those treated unquestionably became reinfested to some extent. As apples were not graded at that time, no attempt was made to distinguish differences in the crop borne by trees sprayed and those left unsprayed as checks, beyond the mere number of the injured and uninjured apples; but results which I shall presently describe make it certain that the actual percentage of benefit would have been much greater than that indicated by these figures if I had also taken account of differences in size and quality of the fruit.

Because of repeated reports of general and important, though slight, surface injuries to apples by insects in summer and fall, I sent an assistant, Mr. E. S. G. Titus, through southern Illinois in June and July, 1901, to observe and collect examples of these injuries, and such insects as might be held responsible for them. Quantities of blemished fruit were sent to the office for careful study, and as a means of rearing any insects which it might contain.

From this investigation it appeared that much the greater part of the injury complained of was due to the plum-curculio, and that the control of this insect would virtually protect the apple—a fact reported to the Illinois State Horticultural Society for that year, and published in its Transactions (p. 148).

Pursuing the subject further, I read at the meeting of this same Society in 1902 an article* prepared by Mr. Titus, the greater part of which was given to the work of the plum-curculio in the apple orchard. In addition to a report of many careful observations, an important suggestion was made in this paper to the effect that, since injury to the fruit was least in well-cultivated orchards, cultivation

*"Insects, other than the Codling-moth, Injurious to the fruit of the Apple," by E. S. G. Titus. Trans. Ill. State Hort. Soc., Vol. 36, pp. 158-162.

at a time when the bulk of the curculios are in the ground passing through their transformations might have the effect to diminish their number by killing them in the pupa state. For this purpose, it was said, a midsummer plowing would be necessary, followed by harrowing to break up the clods and expose the pupæ more thoroughly to the weather. The prompt destruction of the fallen fruit and spraying of the trees with Paris green were also prominently mentioned.

The following year, in a paper* on "The Curculio and the Apple" presented to the State Horticultural Society, Professor C. S. Crandall, of the Horticultural Department of the Illinois Experiment Station, gave the results of a season's work, experimental and entomological, in an orchard in the western part of the state. This article reports the writer's observations, and those of his assistant, Mr. James R. Shinn, with respect to many points of interest in the life history and habits of the plum and the apple-curculios, their numbers in the apple orchard, and their injuries to the apple, together with the outcome of certain spraying experiments made as a test of the insecticide method of controlling their injuries. Entomologists will be especially interested in the precise details of the life history and in minor particulars concerning the habits of these species.

The spraying operation was reported as unsuccessful, even thirteen to sixteen applications of Paris green, extending from May 15 to August 15, seeming virtually without effect. As only 120 trees were used in these experiments out of an orchard of one hundred and twenty-five acres, and as these experimental trees were divided into plats of 10 trees each, it is evident that the sprayed trees were subject to continued invasion from the surrounding orchard, sufficient, possibly, to obliterate the results of the treatment. A suggestion which I have already mentioned—that of plowing and harrowing infested orchards in midsummer to destroy the pupæ in the earth—is here reinforced with numerous exact observations as to the time of pupation, and the depth to which the curculio larvæ penetrate for their pupal transformations.

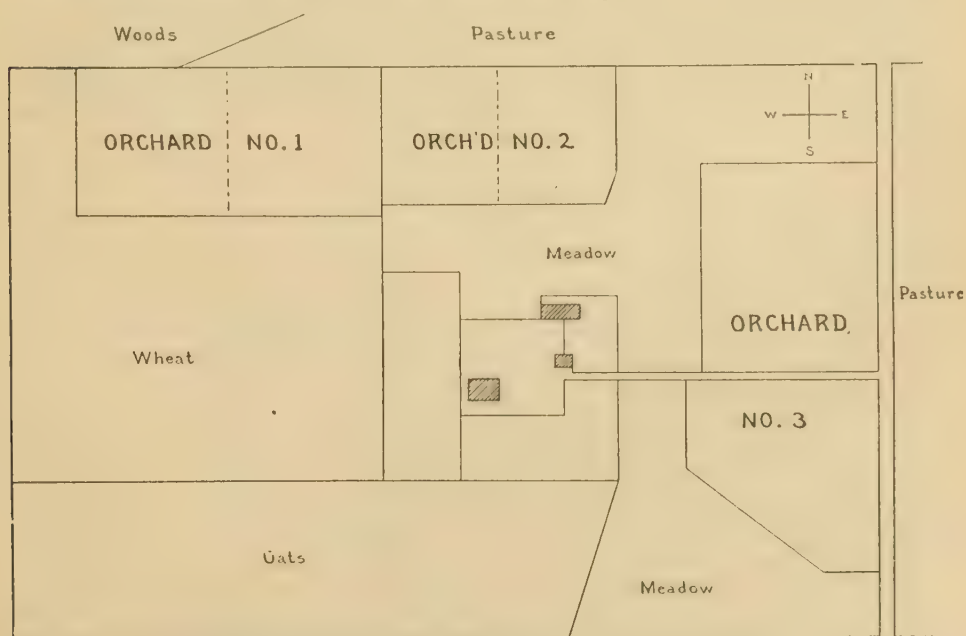
EXPERIMENTS OF 1904.

Owing to the unfavorable outcome of these experiments of 1903 for the control of curculio injuries by the use of insecticides, it became important that measures should be taken to test anew the usefulness of the arsenical sprays, especially as these are necessary to any program of fairly complete protection to the crop of apples

*Trans. Ill. State Hort. Society, Vol. 37, pp. 176-189.

on the trees. Destruction of windfalls and midsummer plowing have the disadvantage that they lock the stable door after one of the horses, at least, is stolen, since they can at most prevent only injuries by the new brood of curculios appearing after midsummer. In the absence of poison sprays, an orchard freed of curculios in midsummer—if this is possible—by plowing and harrowing, would be liable to invasion and serious injury later in the season by insects entering it from outside, and would also be exposed to injuries in the spring and early summer of the following year. With these facts in mind, I undertook, in 1904, a field experiment in southern Illinois intended to test the practical value of an arsenical poison directed immediately against the plum-curculio, with the understanding that similar experiments were to be carried on by the Horticultural Department of the State Experiment Station in another part of the state. My experiment was placed in charge of my field assistant, Mr. E. P. Taylor, and this report is based on his field notes and specimens.

The farm selected, after an examination of some twenty-five fruit farms in southern Illinois, contained three small orchards aggregating eighteen acres. It was situated two miles south of Carbondale, in Jackson county. These orchards were chosen partly because of the considerable crop which they bore—an unusual thing that year—and also because the separation of the varieties with which they were planted, enabled us to make, in most cases, check and experimental plots of the same variety.



SITE AND SURROUNDINGS OF EXPERIMENTAL ORCHARDS

The insecticide used was a compound of arsenate of soda and acetate of lead commonly known as the arsenate of lead. It was made by dissolving 12½ ounces of the acetate of lead and 5 ounces of arsenate of soda in separate vessels, and pouring the two solutions, one after the other, into a barrel with 50 gallons of water. Two barrels were placed in the wagon at once, each with a No. 2 Morrill and Morley spray pump carrying two lines of hose about twenty-five feet long, furnished with twelve-foot extension poles fitted with double Vermorel nozzles.

In spraying, as high a pressure was used as could be kept up by hand; and a fine mist of the spray was forced into the trees from every side, care being taken to wet thoroughly all parts of the foliage without causing the drops to run in streams upon the leaves. The varieties of apples in the orchard will be referred to in giving the results of the experiments.

Three sets of experiments were made by spraying four, six, and eight times respectively, at intervals of about ten days, beginning May 6 to 10, and ending July 28. At the time of the first spraying at Carbondale, the apple-trees were in their first full bloom.

RESULTS OF EXPERIMENTS.

As a basis for the discussion of the principal results of this experiment, I have prepared the accompanying table showing especially the differences in quantity, number, and quality of apples borne, by trees sprayed and by those without treatment. This table, it will be noticed, is divided into two parts, an upper and a lower, and for convenience in reference I have numbered the vertical columns from 1 to 12 and the horizontal sections of the table from 1 to 8.

CURCULIO SPRAYING EXPERIMENTS

Sections	Columns	1	2		3	4	5	6
	Plot	Times spray- ed	Trees used		Apples picke			Injured percent.
			No.	C't'd	Date	Bushels	Number	
1	I. Check Exper.	0	115	4	S. 16-20	15.5	2,617	92.2
		4	111	4	S. 16-20	23.9	3,308	28.59
2	II. Check Exper.	0	34	3	Jl. 26-29	11.4	2,593	21.4
		6	32	3	Jl. 26-29	16.	3,782	10.3
3	III. Check Exper.	0	20	3	S. 17	16.25	2,770	95.6
		6	20	3	S. 17	22.	3,063	30.7
4	IV. Check Exper.	0	145	(9) 4	Jl. 15	6.44	1,540	91.1
		8	119	4	S. 16-20	24.44	3,198	18.5

CURCULIO SPRAYING EXPERIMENTS—Continued.

Sections	Columns	7	8	9	10	11	12
	Plot	Injuries prevented per cent.	Yield increased per cent.	Bushels			Value increased times
				No. 1	No. 2	No. 3	
5	I. Check Exper.	69.	54.	1.5 17.16	6.2 5.5	7.8 1.16	2.75
6	II. Check Exper.	48.	40.				
7	III. Check Exper.	68.	34.	.75 12.06	3.75 3.25	11.66 6.66	2.5
8	IV. Check Exper.	80.					

Orchard 1 (Plot I.).—By an examination of this table it may be seen (Section I, Columns 1 to 5) that all the apples on 4 trees of Plot I. out of 111 of the Ben Davis variety which had been sprayed four times with arsenate of lead, were picked, measured, counted, and carefully examined between the 16th and the 20th of September, and that all the apples on 4 other trees of this plot out of 115 Ben Davises which had been left unsprayed as a check, were also picked, measured, counted, and similarly examined at the same time. These two lots of 4 trees each had been so selected at the beginning of the experiment from the whole number in each lot as to make the check lot the nearest possible duplicate of the lot which had been sprayed, except, of course, in the mere matter of spraying*

SPRAYED 4 TIMES

NOT SPRAYED



ORCHARD NO. 1. APPLES COUNTED FROM STARRED TREES

*The four sprayed trees used for comparison with the four check trees are those starred in the sixth row from the middle line of the orchard. The four trees used as checks are among those starred in the fifth and ninth rows from the middle line.

The 4 trees not sprayed yielded 15.5 *bushels* of apples, and the 4 trees sprayed yielded 23.9 bushels (Section 1, Column 4), the bulk of the yield being thus 54 per cent. greater for the sprayed trees than for those unsprayed (Section 5, Column 8). In other words the trees which had been treated, yielded one and a half times as large a *quantity* of apples as those which had not been sprayed.

The *number* of apples from the 4 trees not treated (Column 5) was 2,617, while that from the trees treated was 3,308—a difference of 26 per cent. in favor of the sprayed trees. That is, the sprayed trees bore a fourth *more apples* than those which had not been sprayed. We should notice, in passing, that the apples from the trees not treated ran 169 to the bushel, and that those from the treated trees ran 139 to the bushel—a difference of 21 per cent. in average size of fruit in favor of the sprayed trees. That is, the apples on the trees which had been sprayed were one fifth *larger*, on an average, than were those from the other trees.

All these differences were apparent without any special examination of the fruit with reference to injuries by curculios. When these curculio injuries were distinguished and tabulated (Column 6), it was found that 92.2 per cent. of the apples on the unsprayed trees had been injured by curculios making feeding-pits, egg punctures, or both, and that 28.6 per cent. of the apples on the sprayed trees were so injured. A simple calculation from these data shows (Section 5, Column 7) that 69 per cent. of the apples which would have been injured if no treatment had been applied, had been protected from injury by the arsenate spray.

Next, the total product of both lots of trees was separately and very carefully graded as No. 1's, 2's and 3's, by the standards of the American Apple Growers' Association adopted in 1903, (Section 5, Columns 9, 10, and 11,) with the result to show that the 4 check trees yielded $1\frac{1}{2}$ bushels of No. 1's, and the 4 sprayed trees, 17.16 bushels; that the check trees yielded 6.2 bushels of No. 2's, and the sprayed trees, $5\frac{1}{2}$ bushels; that 7.8 bushels of No. 3's were borne by the check trees, and 1.16 bushels by the trees which had been sprayed. (See Plates I. and II.)

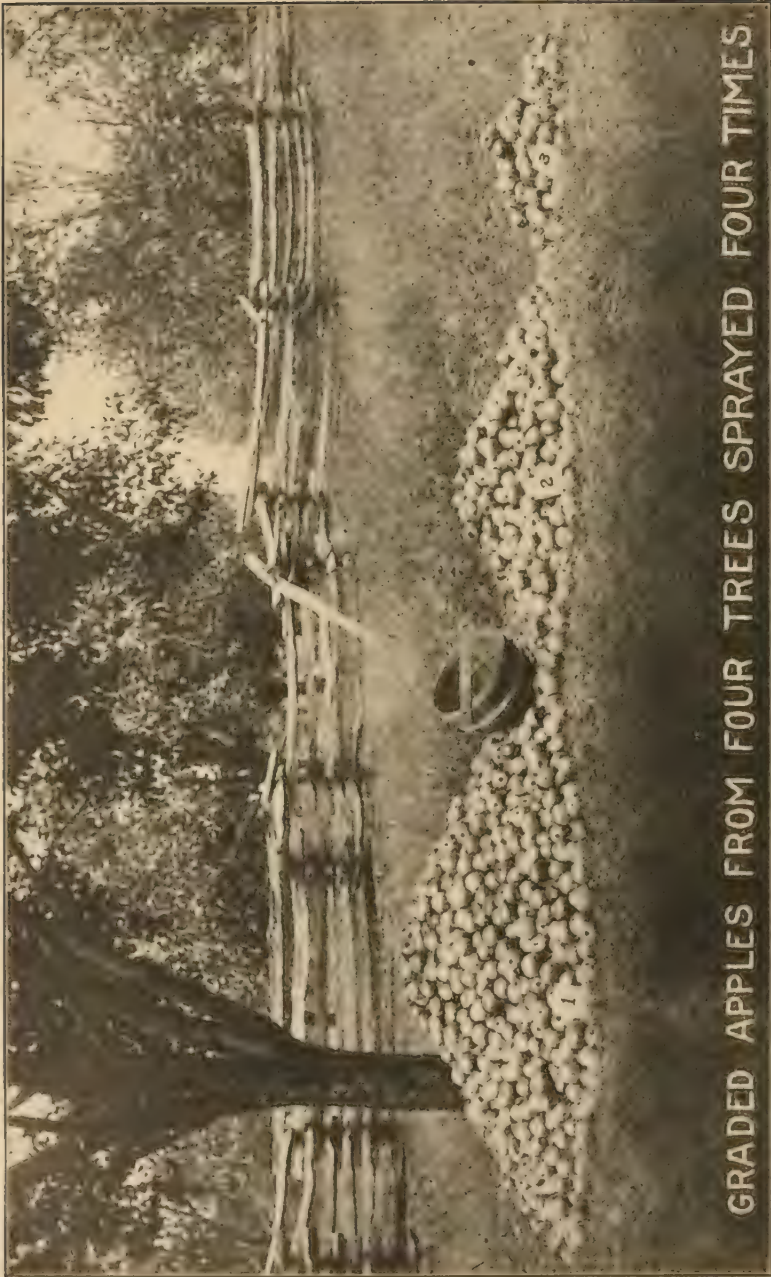
According to the best estimate we can make of the market values of these three grades, if the No. 1 apples sell for \$1, No. 2's might be expected to bring 75 cents, and No. 3's, 25 cents or thereabouts. Applying these estimates to these various lots of apples, it appears that the actual value of the crop from the treated trees was $2\frac{3}{4}$ times that from the trees which had not been treated (Column 12).

To see whether the outer rows of trees were any more likely to be heavily infested by curculios than the inner,—whether curculios entering the orchard from outside would accumulate upon the outer rows,—three trees in the sprayed lot were examined, one from the middle and one from each end of the row farthest removed from the check. No differences in amount of curculio injury were found in these trees, as compared with the average for the plot in general, with the exception of one of the three, which stood at a corner of the orchard next a fringe of forest trees and brush. The fruit of this tree, notwithstanding the four thorough sprayings with arsenate of lead which it had received, had been injured by curculios to the amount of nearly 87 per cent., showing an extensive immigration into the orchard from the adjoining woodland. As this contained both hawthorn and wild cherry-trees it doubtless furnished a constant breeding ground for curculios.

Foreseeing difficulties of this kind, and also the probability of a mutual influence of check and experimental plots, the precaution had been taken to select, quite early in the season, for comparison, four trees from the center of each plot, and it is thus quite certain that no outside interference or intermingling of effects influenced the contrast obtained in this experiment.

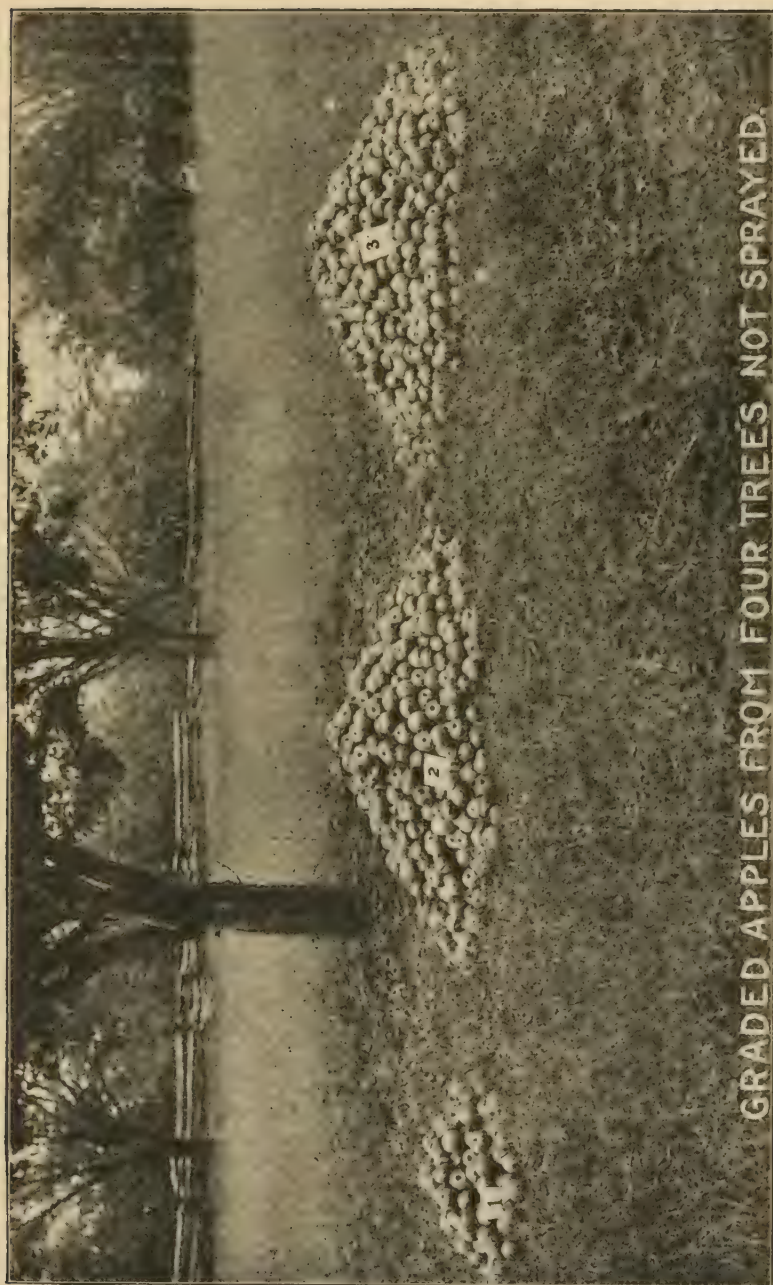
Orchard 2 (Plots II. and III.).—We turn next to the second orchard (Sections 2, 3, 6, and 7), one half of which was sprayed six times in succession, the other half being left as a check. As a part of these apples were of an early variety (Benoni), and a part were of a late variety (Ben Davis), I will give the results for these two varieties separately.

Thirty-two Benoni trees (Plot II.) were sprayed six times in this experiment, in comparison with 34 Benoni trees left as a check, and the apples borne by 3 trees from each of these two lots were picked, measured, counted, and examined July 26 to 29 (Section 2, Columns 1 to 5), the two sets of trees having been so selected as to make the check lot the nearest possible duplicate of those which had been sprayed. The 3 trees not sprayed yielded 11.4 bushels of apples, and those which had been sprayed yielded 16 bushels (Column 4)—an increase of 40 per cent. in the bulk of the yield as a consequence of the spraying. The 3 trees which had not been treated bore 2,593 apples, while the 3 treated trees bore 3,782 (Column 5)—a difference of 47 per cent. in favor of the treated trees. That is, the sprayed trees bore nearly half as many apples again as those which had not been sprayed. The average size of the apples was approximately the same for both lots—228 per bushel for the untreated trees, and 236 for the treated.



GRADED APPLES FROM FOUR TREES SPRAYED FOUR TIMES.

PLATE I.



GRADED APPLES FROM FOUR TREES NOT SPRAYED.

PLATE II.

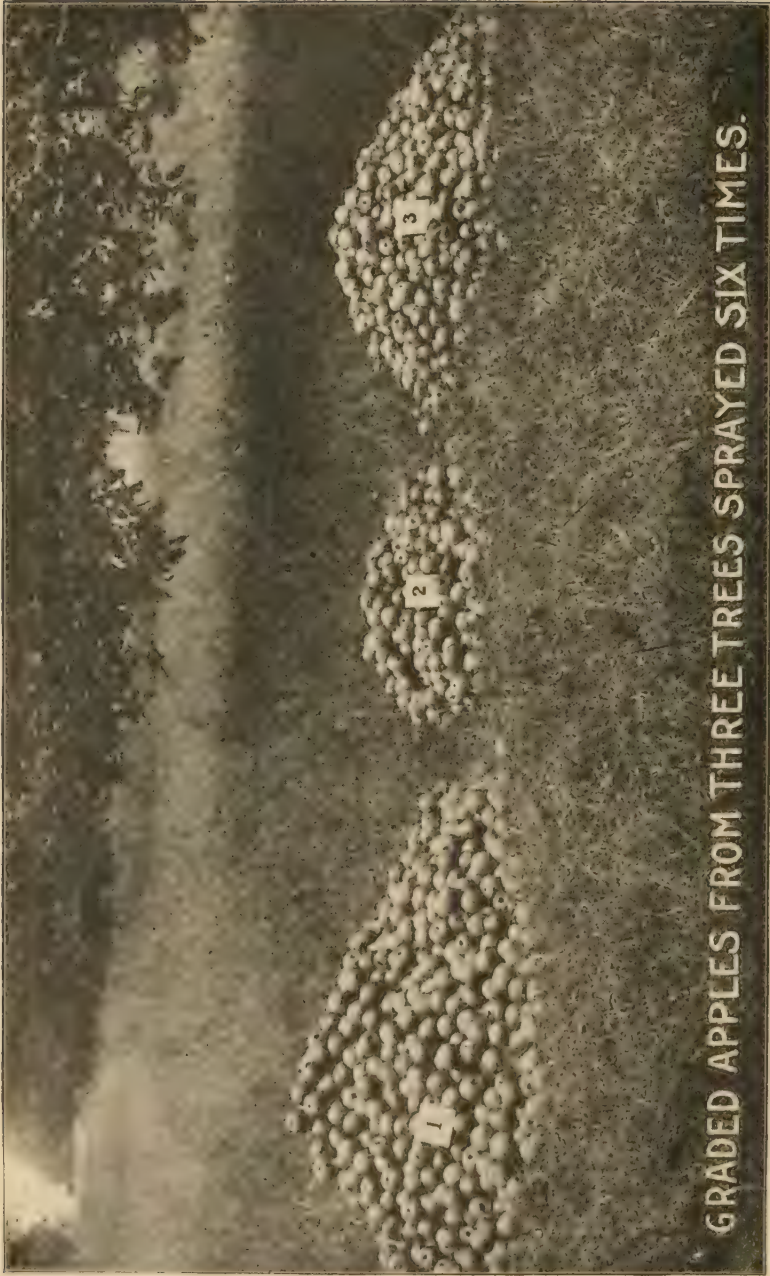
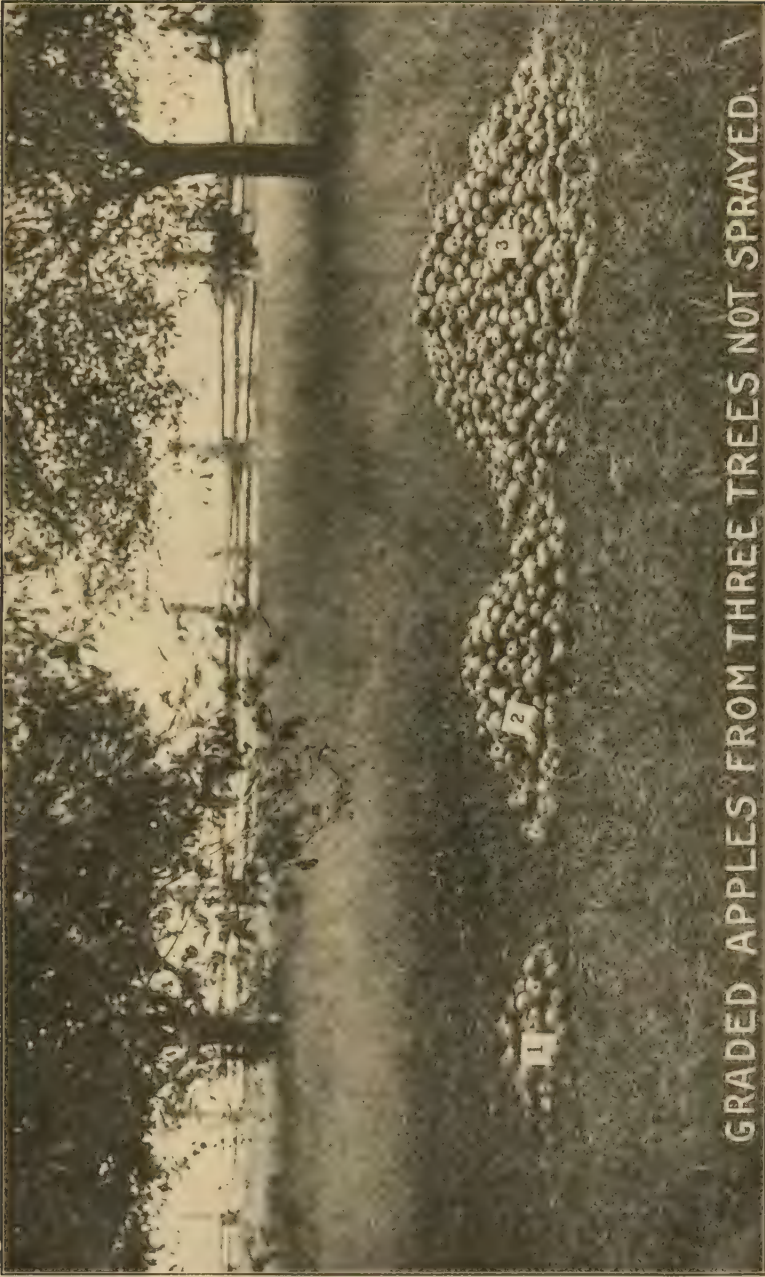


PLATE III.



GRADED APPLES FROM THREE TREES NOT SPRAYED.

PLATE IV.

Turning next to the ratios of curculio injury to these Benoni apples (Column 6), we find that 21.4 per cent. of the fruit of the unsprayed trees had been injured by curculios, and 10.3 per cent. of that on the sprayed trees, 48 per cent. of the apples which would have been injured having been protected from injury by the arsenical spray. These Benoni apples were harvested in July, but were not graded into market classes. I consequently have no data as to the total money benefit of the spraying shown by this Plot II.

On the other part of this orchard (Plot III.) sprayed six times (Sections 3 and 7), were 20 Ben Davis trees which are to be compared with an equal number of this variety left unsprayed as a check. From each of these lots again 3 trees were taken for critical comparison of the product of those sprayed with that of those unsprayed (Section 3, Columns 1, 2, and 3). The final count on all these trees was made September 17. The 3 trees not sprayed gave $16\frac{1}{4}$ bushels of apples, while the 3 trees sprayed yielded 22 bushels (Column 4)—an increase of 34 per cent. in quantity of apples as a consequence of the spraying. The 3 Ben Davis trees which had not been treated bore 2,770 apples, while the 3 treated trees gave 3,063 (Column 5)—a difference of only 11 per cent. in favor of the treated trees. The unsprayed apples on these trees ran 170 to the bushel, and the sprayed apples, 139 to the bushel—a difference of 24 per cent. in size of fruit in favor of the trees which had been sprayed.

With respect to the curculio injury to these Ben Davis apples we find that 95.6 per cent. of the unsprayed fruit had been injured by curculios, and 30.7 per cent. of that sprayed; or, in other words, that 68 per cent. of the apples which would have been injured had been protected from injury by the treatment received.

Looking now to the quality of the fruit from these Ben Davis trees, which had been sprayed six times in all (Section 7, Columns 9, 10, and 11), we find that the 3 unsprayed trees examined gave a yield of $\frac{3}{4}$ of a bushel of No. 1 apples, while the 3 sprayed trees yielded 12.06 bushels; that the unsprayed trees gave $3\frac{3}{4}$ bushels of No. 2's, the sprayed trees $3\frac{1}{4}$ bushels; that the unsprayed trees yielded $11\frac{2}{3}$ bushels of No. 3's, and the sprayed trees $6\frac{2}{3}$ bushels. (See Plates III. and IV.) Reducing these quantities to comparable money values by the prices already assigned, we find that the actual value of the crop from the treated trees was $2\frac{1}{2}$ times that from the trees which had not been treated.

Orchard 3 (Plot IV.).—In the third and last orchard on which I have to report, the check and the experimental sections do not correspond closely, the sprayed trees being all Winesap and Ben Davis, late varieties only, and the check lot almost entirely of early varie-

ties. As the early varieties were harvested July 15, they were less exposed to injury than the fruit on the sprayed trees, which was harvested from September 16 to 20. This is a difference, however, which tends to diminish the contrast between the sprayed and unsprayed trees, and thus to show, if anything, a smaller result from spraying than was actually obtained.

The Winesap and Ben Davis trees, 119 in number, were sprayed eight times in succession, and the fruit from 4 of these trees (3 Ben Davis and 1 Winesap) was picked and examined with reference to curculio injuries. The unsprayed orchard used as a check on this experiment contained 145 trees, all Sops of Wine and other early varieties except 4 Ben Davis (see Section 4, Columns 1, 2, and 3). The fruit from 9 of these check trees was examined July 15, all Sops of Wine except 1 Ben Davis. These yielded 3,463 apples, making $14\frac{3}{4}$ bushels, equal to 1,540 apples, or 6.44 bushels from 4 trees (Columns 4 and 5), while the 4 trees sprayed, the apples from which were picked September 16 to 20, yielded 3,198 apples, making $24\frac{1}{2}$ bushels. These differences in number of apples and bulk of yield can not properly be taken into account in this case, because both might well be attributable, at least in part, to the difference in variety between the sprayed and the check trees from which the fruit was counted.

The curculio injuries on the 9 unsprayed trees had affected an average of 91 per cent. of the apples (Column 6), and on the 4 sprayed trees, an average of $18\frac{1}{2}$ per cent., from which it appears (Section 8, Column 7) that 80 per cent. of the apples which might have been injured by curculios if no treatment had been applied, had been saved from such injury by the arsenical spray. Here again it is possible that a varietal difference in susceptibility to curculio injury may have affected these percentages.

COST OF THE OPERATION.

The reader will be especially interested to know the cost of our operation, figured in terms practical to the fruit grower. I have worked this out in full detail for the 292 trees sprayed in these orchards, including the actual price of materials purchased in the ordinary markets, the amount of materials used, and the labor of application at \$1.25 a day and board for men employed, and \$2.50 a day and feed for a team. Without entering into details, unnecessary for my purpose, I find that the total cost ranges from 4 to 5 cents per tree for each treatment, or 17 cents per tree for the four treatments found most effective. Of this only 2 cents was for materials, the remaining 15 cents being for labor of man and beast, much of which, in many cases, the fruit grower might supply without special outlay.

SUMMARY OF SPRAYING RESULTS.

Finally, to sum up in a word the most important practical results of the orchard experiment with arsenate of lead, we may say that four sprayings of apple-trees of late varieties, exposed to a very heavy attack by the plum-curculio, the first spraying applied in early May just as the trees are coming into bloom, and the others at intervals of 10 days thereafter, the whole operation costing 17 cents per tree, may be expected to increase the yield of the orchard about one half, to increase the average size of the fruit by about a fifth, and so to improve the quality of the apples that they should be worth from $2\frac{1}{2}$ to 3 times as much as if the orchard had not been sprayed.

POISON TESTS OF SPRAYED APPLES.

The arsenate of lead used in experiments described in this paper is an unusually adhesive insecticide, remaining upon trees in visible quantity weeks and even months after it has been applied. Evident traces of the mixture were still visible in October on leaves which had fallen from trees sprayed with the arsenate of lead July 4. In view of this fact is seemed to me important that experiments should be made to determine the amount of poison carried by apples treated with this insecticide within a reasonable limit of time after the spray was applied. I consequently directed, in 1905, the spraying of apple-trees with various arsenical compounds, and among others with the home-made arsenate of lead, and obtained analyses of the peelings of apples so sprayed taken from 2 trees within a day of the application of the insecticide, and from a third tree 2 months thereafter.

The first of these trees, of the Duchess variety, received 2 sprayings with the arsenate of lead—the first June 9 and the second July 4—not having been previously sprayed at all that year. In both these sprayings the insecticide was used 4 times the common strength— $12\frac{1}{2}$ ounces of acetate of lead and 5 ounces of arsenate of soda to $12\frac{1}{2}$ gallons of water instead of the usual 50 gallons.

The next day, July 5, six apples, averaging two and a fourth inches in diameter, were carefully picked from this tree by the stem and peeled at once, the apple being held upon the point of one knife while it was peeled with another, to avoid removing any part of the poison unnecessarily. The peelings were then dropped into a dry, clean, new Mason jar and submitted for chemical analysis to Dr. Wm. M. Delm, of the Chemical Department of the University of Illinois. It should be said that the weather in the interval between spraying and collection of the apples had been dry. According to Dr. Delm's report, these apple peelings thus collected yielded 36.6 parts per million of arsenious acid, enough to equal .2562 grains of

arsenic to an avoirdupois pound of the sample peelings. This would mean that one would have to eat approximately four pounds of apple peelings to get a grain of arsenic if the fruit were taken the day after spraying from a tree which had received four times the usual strength of this insecticide.

Another tree, a Benoni, differed especially in two respects from the foregoing. It had been sprayed three times by the owner earlier in the season, and it was sprayed twice by us—June 9 and July 4—but with arsenate of lead in the strength usual in practical orchard work, that is $12\frac{1}{2}$ ounces of acetate of lead and 5 ounces of arsenate of soda to 50 gallons of water. The earlier sprayings were as follows: First spraying about April 3, before the appearance of the bloom, with 3 pounds copper sulphate, 5 to 6 pounds lime, 2 ounces arsenate of soda, and 2 ounces Paris green, to 50 gallons water; second spraying about April 26, just after the bloom had fallen, with 2 pounds copper sulphate, 1 pound Lorenberg's arsenate of lead, 2 ounces Paris green, 3 to 4 pounds lime, and 50 gallons of water. Rain fell more or less for three days after this second spraying. The third spraying, about May 3, was with 2 pounds copper sulphate, 3 to 4 pounds lime, 1 pound Lorenberg's arsenate of lead, 2 ounces Paris green, and 50 gallons of water.

From this tree six apples averaging two inches in diameter were picked July 5, the day after our own second spraying, with the precautions described above. The peelings tested by Dr. Dehn yielded 32.9 parts of arsenious acid per million, equivalent to .2303 grains of arsenic per pound of the samples.

It will be noticed that, although the insecticide here used contained only one fourth as much of the arsenate as that applied to the Duchess tree, the percentage of arsenic remaining on the fruit was nearly as large.

The third tree treated was a Rome Beauty, sprayed, like the preceding, three times, April 3, April 26, and May 3, approximately, with combinations of Bordeaux mixture and arsenical insecticides, and further sprayed, June 9 and July 4, with home-made arsenate of lead at the rate of $12\frac{1}{2}$ —5— $12\frac{1}{2}$; that is, like the first tree, with four times the usual strength.

The apples were picked from this tree September 4, two full months from the time of spraying. Those chosen showed more than the average amount of residue of the insecticide on the fruit. They were picked into baskets, poured into a box where they were packed closely by hand, and shipped to the office at Urbana, being given average shipping treatment. Ten apples were later taken from the box and carefully peeled, the peelings being submitted, as before, to Dr. Dehn for examination. Notwithstanding the long exposure in the orchard, the report on the arsenical contents of this

material is very similar to that of the preceding determinations. The arsenious acid was found at the rate of 40.1 parts per million, enough to give .2807 grains per pound of the apple peelings. One would thus have to eat about three and a half pounds of these peelings to get a grain of arsenic.

Two grains of arsenic is a fatal dose, and one thirtieth to one tenth of a grain is a medicinal dose. For the first, one would have to eat seven or eight pounds of these apple peelings; and for the second, from two to seven ounces. While these facts are not at all alarming, they suggest discretion in the use of this insecticide and in the subsequent handling and disposal of the apples. We also need further experiment with various strengths of the spray and with various kinds and amounts of subsequent exposure of the fruit. Nevertheless, in view of the fact that apple peelings are rarely eaten in any quantity, I think that no hesitation need be felt to substitute the arsenate of lead for the more usual insecticide sprays if the facts here given are borne in mind and duly allowed for.

THE NEUTRAL ZONE IN SPRAYING EXPERIMENTS.

It has been customary in making field insecticide experiments to apply the chosen treatment to a certain area, leaving a corresponding area immediately beside it untreated, as a check, the utility of the treatment being determined by a comparison of subsequent conditions on these two tracts. Attention has already been called by Gillette,* Weed,† and myself‡ to the fact that the results of such experiments must be somewhat affected by the spread of insects from the so-called check plot to the experimental plot, but nothing has been done to demonstrate this proposition experimentally, or to show just how important this mutual influence of check and experimental plots may be.

In the spraying experiment conducted in Orchard I., as above described in this article, the opportunity was improved to ascertain to what extent the curculios spread from one part of the orchard to another—to what extent, that is, one must guard against vitiation of results of spraying experiments by the spread of the curculios from unsprayed trees to those which have been sprayed. This orchard, it will be remembered, was divided into two equal parts, each virtually square, on one of which all trees were sprayed four times with arsenate of lead, beginning May 6 and following at intervals of ten days thereafter, while the other part was left unsprayed as a check. The apples in this orchard were of the Ben Davis variety, and were harvested September 20. At this time all the apples

*Bull. 9 (1890), Ia. Agr. Exper. Station, pp. 383-384.

†Bull. 23 (1890), Ohio Agr. Exper. Station, p. 226; *Agricul. Science*, Apr., 1890, p. 97.

‡"Arsenical Poisons for the Codling-moth." Bull. 1 (1887), Office State Ent. Ill., p. 9; Fifteenth Report, State Ent. Ill., p. 13.

borne by three trees which had not been sprayed, but which stood in the row next the sprayed half of the plot, were counted and examined in comparison with the product of ten other trees taken at various points in this unsprayed part of the orchard. (See diagram, p. 83 and table on p. 97). Eighty-one and five tenths per cent. of the apples on these 3 trees next the experimental plot had been injured by the curculios, and $90\frac{1}{3}$ per cent. of the apples on the 10 trees farther back,—a difference of 8.8 per cent. of all the apples on these trees, which can only be accounted for on the supposition that more curculios went from the three trees nearest the sprayed half of the orchard *into* that half than came into it *from* that half.

Next, three trees which had been sprayed and which stood in the row nearest the unsprayed part of the orchard were similarly examined, with the result that $43\frac{1}{3}$ per cent. of the apples on these trees were found to have been injured by curculios, while $26\frac{1}{2}$ per cent. of the apples on 10 other trees taken elsewhere in this sprayed plot were so injured. That is, 16.8 per cent. more of the fruit on the trees standing nearest the unsprayed portion was injured than on the trees farther back.

It will be seen that the increase of average injury to apples on unsprayed trees near the check plot was nearly twice as great as the decrease of injury on the unsprayed trees standing next the experimental plot. This can only mean that the excess of curculios on the unsprayed fruit to which their greater injury was due did not all come from the unsprayed trees in the adjoining row, but that approximately half of them must have come in from remoter parts of the experimental plot. In order to see how far this mutual effect of one plot on the other actually extended inward in either direction from the dividing line, apples were picked and counted separately for each tree from a series of 14 trees running lengthwise of the orchard at right angles to the dividing line between the two plots. It was found in this way that notable diminution of curculio injury on the one side and increase on the other did not extend so far as the third row from the dividing line in either direction; in other words, that it seemed limited to the first two rows on either side of that line.

To test this conclusion in a more general way, the percentages of curculio injury to apples were figured separately for all trees in each cross-row from which any fruit was picked, beginning at the outer end of the sprayed half of the orchard and ending at the opposite end of the unsprayed half. The details are shown on the accompanying table (p. 97,) from which it will be seen that 12 trees in six different transverse rows of the sprayed half of the orchard, ranging from the first to the ninth row, bore from 26 to 30 per cent.

of injured apples,—excluding for the moment a single exceptional tree in the seventh row, which gave but 16 per cent. of injury. That is, with this exception, the ratios ran from row to row with virtual uniformity as far as the third row from the dividing line. In the other half of the orchard, that left unsprayed as a check, the injury on 10 trees distributed through six rows—from the fourteenth to the twenty-second—ranged from 87 to 99 per cent., and in this series also there is no uniform progression as one goes from the dividing line outward.

We may make this influence of a proximity of check and experimental plots more definitely apparent by saying that if the two adjacent rows only had been brought into comparison the difference in injured apples would have been only 38 per cent., while the real effect of the treatment was a difference of 63 per cent. Or, to put the facts still more definitely, a comparison of the product of the adjacent rows would indicate a saving, by spraying, of 47 per cent. of the apples which would otherwise have been injured, while the real saving was one of 70 per cent. The apparent benefit would be but two thirds the actual.

We find, in short, two to four rows running through the center of this orchard, one or two in each of the two plots, the product of which has been rendered unfit for use in an exact comparison of the condition of these two plots with reference to experimental results. Such a strip must evidently always exist under similar circumstances; a kind of neutral zone belonging properly to neither plot, and unfit for comparison or for use in a discussion of the outcome of an experiment. The importance of this conclusion is evident when one scans the published statements of similar experiments and finds that in many cases the adjoining plots are so narrow that nearly or quite all of both must lie in this neutral zone. Sometimes, indeed, one can not learn from the description of an experiment the form or dimensions of the plots, and consequently can not judge how far some portions of each or either may have been removed from this central belt. Any experiment of the kind on diffusible insects or fungi which does not take these facts into account, and from the discussion of which a sufficient central strip is not omitted, must be regarded as unsatisfactory, if not rejected outright as inexact.

Both the amount and the extent of the mutual influence of check and experimental plots will vary greatly with different insects, and with the same insect species under different conditions of abundance and different kinds of treatment. Where infestation is unusually heavy this interference with effects of treatment would, other things being equal, be more pronounced. To determine, in any case, how much of a central strip must be omitted, it would be necessary to

make some such preliminary test as I have described, or, if the entire product of the plots were harvested, to keep the different parts of it distinct, rejecting those data which show an evident influence of one plot upon the other.

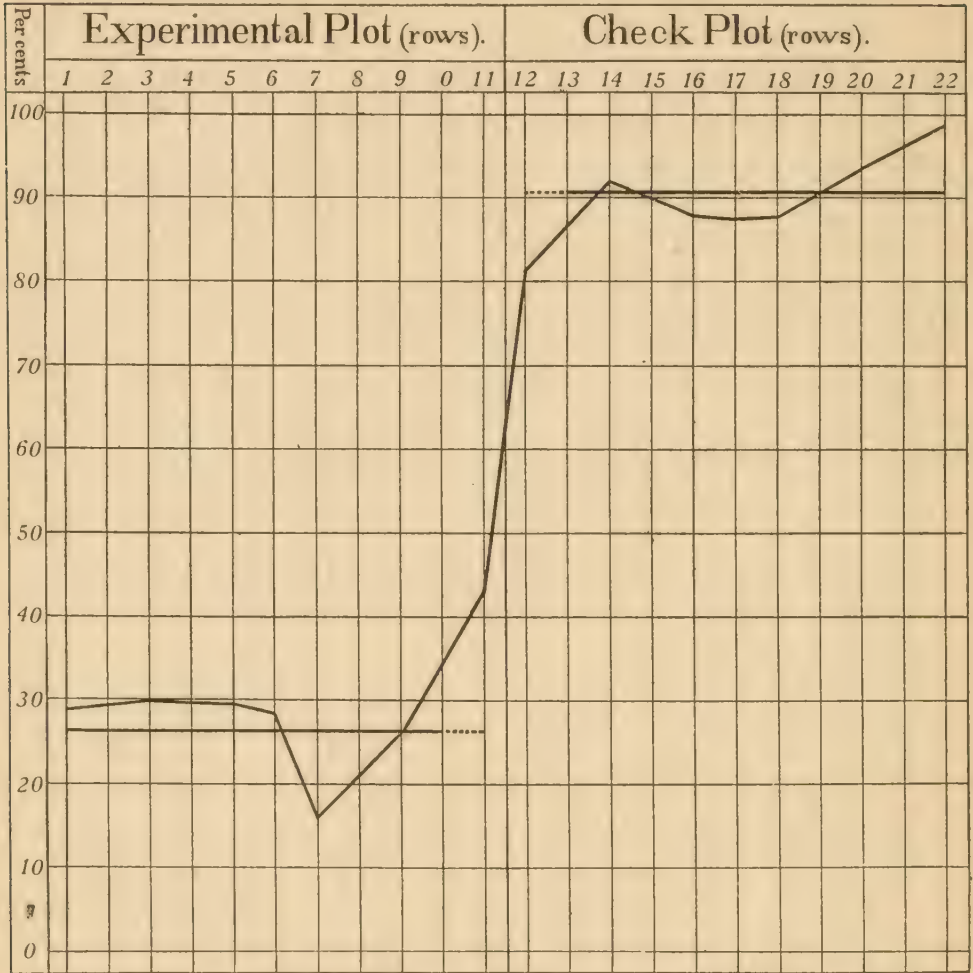
In an ordinary plot experiment, if I infer from the outcome of the treatment of a lot of trees in the midst of an orchard what will happen if an entire isolated orchard were similarly treated, I tacitly assert that such a plot, so situated, is so like an isolated orchard in all that concerns my experiment that the one may be substituted for the other. As a matter of fact, however, while a small part of an orchard is analogous to the whole of it in many particulars, it may differ from the whole in just those particulars and conditions which most strongly affect my problem.

Since reasoning by analogy is the only process possible in such a case, we must first make this analogy practically complete—must establish the essential similarities between our experimental plot and an entire orchard—before we can reach any safe conclusion as to the practical application of the experimental results. This I have done to the best of my ability in the experiment here referred to, and I venture to think that like results may be expected, under similar conditions, from a repetition upon entire orchards of the treatment here described.

ORCHARD I. SPRAYED PLOT, ROWS 1 TO 11; AND CHECK, ROWS 12 TO 22

Row	Trees examined	Per cent. injured	Average
1	2	28.95	26.53
2	0		
3	1	29.89	
4	0		
5	3	29.73	
6	4	28.59	
7	1	16.	
8	0		
9	1	26.	
10	0		
11	3	43.33	43.33
12	3	81.5	81.5
13	0		90.33
14	2	92.23	
15	0		
16	3	88.08	
17	1	87.7	
18	2	87.19	
19	0		
20	1	93.79	
21	0		
22	1	98.96	

DIAGRAM OF SPRAYING EFFECTS WITH ARSENATE OF LEAD.
(Showing mutual influence of check and experimental plots.)



The above diagram is simply a graphic representation of the data of the preceding table. The vertical lines represent the rows of trees in Orchard 1, except the central line, which marks the division between the half of the orchard which was sprayed and the half left unsprayed as a check. The horizontal lines, numbered from 10 to 100, indicate percentages of injured apples. The broken line crossing the diagram from left to right intersects the vertical line for each row at a point corresponding to the percentage of injured apples from that row. It will be noticed that the eleventh row of the series is the experimental row next to the check plot, and that the twelfth is the check row next to the experimental plot.

The influence of these plots one upon the other is shown by the strong, upward course of the broken line from the ninth to the eleventh rows, and the downward course from the fourteenth to the twelfth. The short horizontal lines, one on each side of the diagram, indicate the *average* percentage of injury on check and experimental plots respectively, with the exception of rows eleven and twelve. The distance between the inner ends of these lines is a measure of the benefit resulting from the spray, and the distance from the inner end of each line to the point where the broken line crosses the vertical, is a measure of the influence of the other plot through the unequal interchange of curculios.

THE COTTONY MAPLE SCALE IN ILLINOIS.

The cottony maple scale* is a native insect parasite of the soft maple†, rarely if ever injurious to the scattering trees of this species growing in natural forests, but so destructive to them, and to other ornamental trees as well, where these are grown in rows or groups along streets or in parks and on private lawns, that its control has become an object of primary importance to all owners and lovers of some of our most beautiful and popular American trees. In and about Chicago especially, it has destroyed, within the past five years, thousands of trees, beautiful and valuable in themselves, and still more highly valued because of the associations attached to them. To do our best to save these noble but helpless products of nature from a slow and unsightly death by parasitic disease, must be the welcome duty of all who appreciate the significance of trees in the life of the people, and especially of those who live in our larger cities.

The history of this insect in Illinois since 1867 exhibits successive periods of abundance and of scarcity, each averaging about four or five years for the state as a whole. That is, throughout some considerable part of the state, and often over most of it, the maple scale has been injuriously abundant once in eight or ten years, and its period of abundance has lasted, as a rule, about half this time. In any given locality, however, it has usually been injurious for a much shorter time, often for not more than one or two years. The cessation of its injuries and its virtual disappearance from the trees infested by it have seemingly been due almost wholly to the agency of its insect enemies.

An exception to these statements is presented by the existing outbreak of this insect in northeastern Illinois, and especially in Chicago and its suburbs to the north and west. Here, as shown by observations of assistants of the office who have been repeatedly sent through the park and boulevard systems of Chicago for an investigation of insect injuries to shade trees and other ornamental vegetation, it has certainly been destructively numerous since 1901. Indeed, according to information locally given to Mr. H. E. Weed, of Chicago, it has been continuously injurious over some parts of this area since 1886. This general persistence of an injurious infestation within the same district for so long a period is due to the

**Pulvinaria innumerabilis*. †*Acer saccharinum*.



FIG. 1. A Soft Maple Twig badly infested with adults of the Cottony Maple Scale.
About natural size. (J. B. Smith.)

failure of the insect enemies of this scale to multiply at a sufficient rate to check its rapid increase, and this is possibly the consequence of an unfavorable effect of a city environment, although there is some reason to suppose that the cottony maple scale has here extended northward into a latitude more favorable to itself than to the insect enemies which commonly hold it in check.

Although no attempt has been made to define the present area of destructive infestation in Illinois, this scale was reported to me during 1905, in the current correspondence of the office, as locally abundant in fifteen counties, namely, Winnebago, Lake, McHenry, Cook, Dupage, Kane, DeKalb, Ogle, Bureau, and Henry in northern Illinois; Woodford, DeWitt, Sangamon, and Montgomery in central Illinois; and Marion in the southern part of the state. Doubtless the actual area infested by it was much more general than this list would indicate.

The injurious effect of a severe and long-continued drain by the cottony maple scale on the vitality of trees infested by it is unquestionable. Many thousands of soft maple, linden, box-elder, and elm trees in northeastern Illinois are now dead or dying, or have been disfigured by the death of large branches, because of injuries by this insect, and large numbers of such trees have been removed. Private citizens, town boards, and park commissioners have become deeply concerned, and numerous inquiries and appeals for aid have come to this office during the past three years. A lack of available funds has, however, prevented as active a participation in the work of practical experiment and insecticide operation as might reasonably have been expected of the Entomologist's office, and I have been obliged to content myself, in the main, with improving the opportunity to observe, and incidentally to assist, the work of official bodies and private parties for the control of this pest.

I am particularly indebted to Mr. Reuben H. Warder, Superintendent of Lincoln Park, who has kept me acquainted with his work against this and other scale insects, and has made it possible for us to follow his operations in detail to their final results. I am also under obligations to Mr. O. C. Simonds, Superintendent of Grace-land Cemetery, for similar privileges. Our field observations have been mainly made by Dr. J. W. Folsom, Associate in Entomology at the University of Illinois, and by Mr. E. O. G. Kelly and Mr. C. A. Hart, serving as assistants to the State Entomologist. Dr. Folsom also managed a small spraying experiment for me at Grace-land Cemetery in 1905.

The present article, in the preparation of which I have had the valued assistance of Mr. Hart, is intended to give a brief account of

the insect, to review the attempts made to destroy it by means of summer and winter sprays, and to present practical instructions for its mastery where it is still present in destructive or threatening numbers.

A comprehensive article on the insect, prepared by Dr. L. O. Howard, appeared in 1900 in Bull. 22 of the U. S. Bureau of Entomology, and Circular 64 of that Bureau gives a brief popular account of it and of measures to be taken for its destruction. This paper was prepared with special reference to the Chicago situation of 1905. In Bull. 52 of the Bureau, published in 1905, is a paper by Mr. H. E. Weed describing his experiences in spraying against this scale in Chicago, and Mr. S. A. Johnson has reported on some experiments in Denver, Col., with a winter insecticidal treatment. The last-mentioned author has this year made the species the subject of Bull. 116 of the Colorado Agricultural Experiment Station, in which a summer treatment is especially discussed.

FOOD PLANTS.

The soft maple (*Acer saccharinum*) is the tree most generally and heavily infested by this insect. The hard maples, on the other hand, are infested but slightly if at all. The box-elder is also greatly subject to injury, and next to this, perhaps, the linden or basswood. Among the other trees and woody plants often more or less injured, are the elm, honey-locust, black locust, black walnut, sumac, willow, poplar, beech, hawthorn, bittersweet, grape-vine, and Virginia creeper. Dr. Folsom found mature egg-laying females on the horse-chestnut, honeysuckle, dogwood, trumpet-creeper, mulberry, snow-berry, smoke-tree, *Spiræa*, false syringa (*Philadelphus*), and *Wistaria*. Oak, ash, and catalpa are not infested in northern Illinois, but injury to oak is reported from Georgia. According to S. A. Johnson, the pear is most liable to injury among the fruit-trees, and apple, plum, and peach are sometimes infested. Serious damage to fruit-trees is, however, very unlikely. The migrating young, which are often washed from trees by rain, or blown off in considerable numbers, may maintain themselves for a time on a great variety of woody and herbaceous plants, those on the latter, of course, perishing with the advent of frosts.

THE LIFE HISTORY OF THE INSECT.

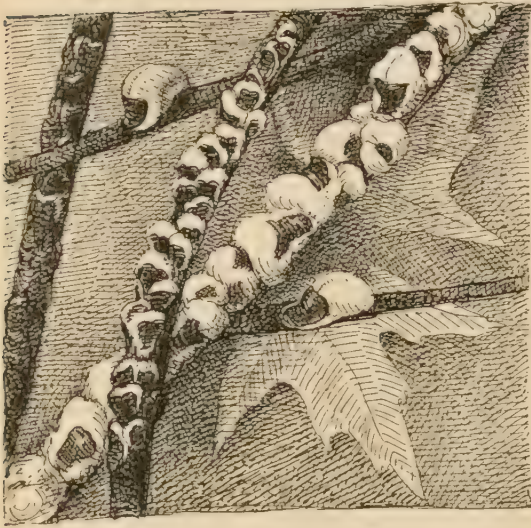


FIG. 2. The Cottony Maple Scale, adult females on twigs. Natural size. (Howard, U. S. Department of Agriculture.)

In early summer this scale, when very abundant, coats the under side of heavily infested limbs with a thick layer of cotton-like waxy masses (Fig. 1, 2), each projecting from beneath a brown cap or scale—the flat body of the mature female. This “cotton” is secreted and the eggs are deposited within it in late May or early June in the latitude of central Illinois, but usually one or two weeks later in the Chicago district.

Something over 3000 eggs are usually laid by each female, the number ranging, in our counts, from 2856 to 3863, with an aver-

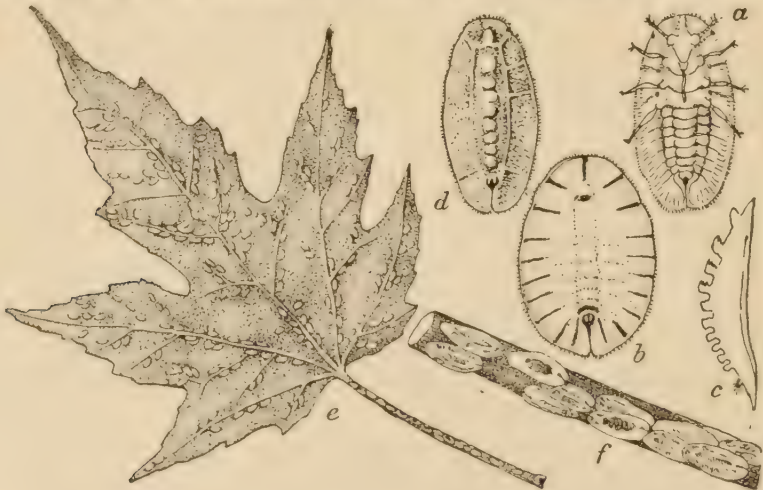


FIG. 3. The Cottony Maple Scale, immature stages: *a*, newly hatched young, underside; *b*, *c*, young female, top and side views; *d*, young male; *e*, *f*, young on leaf and leaf-stem. Natural size shown in *c*. (Howard, U. S. Department of Agriculture.)

age of 3410. These eggs ordinarily hatch in June in central Illinois, in early July in the northeastern part of the state, or later if the weather of the time is unfavorable. Virtually all are hatched, as a rule, by the end of July. The young insects may crawl out on the leaves and establish themselves beside the principal veins on both

surfaces of the leaf, but most abundantly beneath, or else may locate upon the twigs. At this season (Fig. 3) they present the appearance of small, inconspicuous, waxy, elongate-oval scales, applied closely to the leaf. They are usually motionless, but have never-

theless minute legs still capable of service, but invisible unless the insect is turned over. Inserting their tiny beaks into the tissue of the leaf, they suck out the sap, and when the supply of food is large they give off the excess in the form of a sticky fluid, the so-called "honey dew," which moistens the surface of the lower leaves and

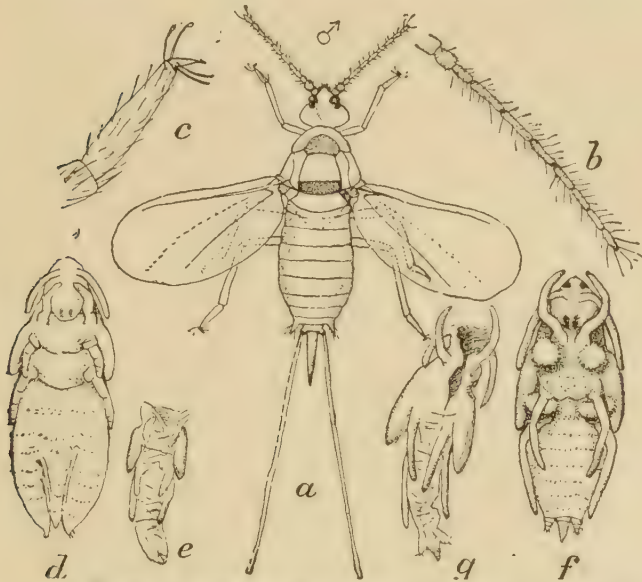


FIG. 4. Male of Cottony Maple Scale: *a*, adult; *b*, *c*, an antenna and leg enlarged; *d*, *e*, second stage of pupa and its cast skin; *f*, *g*, true pupa and its cast skin. All greatly enlarged. (Howard, U. S. Department of Agriculture.)



FIG. 5. The Cottony Maple Scale: adult female in spring, just before the formation of the cottony egg-sac. (Howard, U. S. Department of Agriculture.)

falls on the plants beneath the tree. Under this large and constant withdrawal of sap the leaves turn pale or yellowish, and may fall off prematurely, with the effect sometimes to kill the larger branches or even the entire tree.

The male bark-lice beneath the scales on the leaves reach maturity the same season, and transform to tiny gnat-like insects (Fig. 4) with a pair of delicate wings. They pair with the partly grown females on the leaves, and die at the approach of winter. Before the fall of the leaf in autumn the young females collect on the under side of the smaller branches, where they spend the winter in a more or less dormant condition with their beaks inserted in the wood. They complete their growth in spring (Fig. 5), and in due time produce the so-called "cotton," within which the eggs are imbedded.

THE HATCHING PERIOD.

As the newly hatched young are especially susceptible to the petroleum insecticides, which act by contact, a definite knowledge of the hatching period has an important practical value. In central Illinois this period extends approximately from June 15 to July 20. In and about Chicago it commonly begins about two weeks later, and continues for a period of three weeks, this retardation being apparently due to the higher latitude and to the neighborhood of Lake Michigan. In 1905, for example, Dr. Folsom found that the young began to appear in Chicago about July 1, and were all out by July 21 or a few days later, but that thirty miles west of the city, hatching began about June 20. Mr. H. E. Weed reports, in Bull. 52 of the U. S. Bureau of Entomology, that in 1904 scarcely any eggs had hatched in Chicago by June 25, but that the young appeared rapidly under the influence of a few days of warm weather about July 10. The recorded dates for Colorado approach those given for Chicago. In Washington, D. C., according to Dr. Howard, hatching of the eggs begins usually in late May or early June, and continues into July and sometimes to the beginning of August.

The period varies, in short, as to its beginning time, with the advancement of the season, and once begun, the rapidity of the hatching will depend, other things being equal, on the warmth of the weather. It is also influenced locally by the amount of foliage on the trees, the eggs hatching later and more slowly in a dense tree-top than in one more open to the sun.

SUMMER INSECTICIDE MEASURES.

Owing to the manner in which these insects obtain their food—that is, by sucking the sap through a tubular beak—they are not susceptible to poisoning by way of their food, and the only insecticides available against them are those which kill by contact, and of these the kerosene mixtures have thus far been found the most useful. The most satisfactory of these is the common kerosene emulsion, made by thoroughly and intimately mixing a good grade of kerosene with one third its volume of a strong soap-suds, and diluting with water according to the time of the year when used. Precise directions for preparing and applying this emulsion may be found in the general summary at the end of this paper.

The use of this insecticide for the maple scale dates from experiments made by me in 1884, intended to test the effect of kerosene emulsion on the newly hatched young, and described in the Fourteenth Report of the Illinois State Entomologist. They showed

that practically all these may be killed by dipping the infested leaves in dilute emulsions (those used varying in content from $2\frac{1}{2}$ to 10 per cent. of kerosene), unless the application be delayed too long after hatching. When the young are a week or two old they are partially protected by a waxy covering against the action of the oil. The test of death used was a thoroughly reliable one. The young were at this time so small and transparent that the action of the heart could be readily seen under a microscope, and the cessation of this action was the mark of death depended upon. As the maple scale disappeared from my neighborhood in 1885, no further experiments were made at that time.

In 1904 the Commissioners of the North Shore Park District, above Chicago, of which Robert W. Vasey was president, engaged Mr. H. E. Weed, of Chicago, to treat one hundred and twenty soft maples and box-elder trees in their charge, along the boulevards, for the destruction of the cottony maple scale. A report of this treatment by Mr. Weed was printed in Bull. 52 of the U. S. Bureau of Entomology. The results of his work were submitted to me for examination in August and September, 1904, by Mr. Vasey, who sent me leaves from the trees which had been treated with a 12 per cent. emulsion.

The scale insects on these leaves were carefully examined at my office by Mr. Hart, who found that out of 1781 scales 610 were alive and 1171 were dead.* Practically all the living scales were on the under surface of the leaves, only 1 per cent. of those on the upper surface being still alive. The ratio of the dead to the living on these leaves was 60 per cent.; but as it seemed likely that some scales were dead before the spray was applied, Mr. Vasey sent me, for comparison, at my request, leaves from infested trees not treated. An examination of these untreated leaves showed that 22 per cent. of those on the upper surface were dead and 4 per cent. of those on the lower surface. Making the necessary correction, it was found that 57 per cent. of the scales alive when the trees were sprayed had been killed by the treatment. The spray thus tested was applied August 29.

According to Mr. Vasey, the insects had hatched very slowly that year, owing to the backward season, but had been in condition for treatment with the kerosene spray for some three or four weeks preceding. It will be seen, consequently, that the treatment was too late to produce the full effect upon the young. Further

*The young insects were by this time so opaque that the movements of the heart could no longer be seen; but it was found that living individuals, when displaced and inverted, made slow movements of the legs, and that dead individuals were not only motionless but paler and often discolored, and usually more or less dried up.

work showed that a 15 per cent. emulsion was injurious to the tree, taking nearly all the leaves from the box-elders and the lindens, and half those from the soft maples. In this same year (1904) Mr. S. A. Johnson, of the Col. Agricultural Experiment Station, made a number of laboratory experiments with the summer treatment of this insect, reaching the conclusion that after the young are a week or ten days old they are not easily killed by the kerosene emulsion, but that before reaching this age they may be effectively treated by sprays of as low a strength as 5 per cent.

The following year (1905) Dr. J. W. Folsom, of the University of Illinois, made for me a series of experiments, opportunity for which was provided by the courtesy of Mr. O. C. Simonds, Superintendent of Graceland Cemetery.

A 10 per cent. emulsion of kerosene was applied to several trees of medium size with the use of a Bordeaux nozzle on an extension-pole. A solid stream was first directed against the egg-masses in order to loosen and soak them, after which a very fine spray was applied as thoroughly as possible to both sides of the leaves. A solution of whale-oil soap (one pound to six gallons of water) was applied to an eighth tree by the same apparatus and with the same care.

The effect of the spray was tested by counting both dead and living scales on twenty-five leaves picked at random from different parts of each tree, one series of counts being made just before the spray was applied and another as soon as possible after it had dried away and taken effect. Among the trees receiving the 10 per cent. emulsion of kerosene were one tree sprayed July 3, at the beginning of the hatching period of the scale, one treated July 11, at about the middle of this period, three treated July 19 and 20, at the end of the period, and one treated twice, once at the middle and once at the end. The tree receiving the soap solution was sprayed July 19—that is, at the end of the hatching season.

Four hundred and eighty-four thousand scales, borne by four hundred and fifty leaves from these various trees, were critically examined, and classified as either living or dead. The ratio of benefit—the percentage, that is, of scales actually killed by the spray—was determined in all cases by eliminating from the calculation the scales dead at the beginning of the experiment, and figuring the percentages only on the number of scales alive when the spray was applied. The following table gives the essential data and results of these experiments.

EFFECTS OF EXPERIMENTAL SUMMER SPRAY.

Treatment		No. of trees	Leaves examined	Scales examined	Per cent. killed by spray
Insecticide	Part of hatching period				
10 per cent. Kerosene	Beginning	1	75	48,789	33
10 per cent. Kerosene	Middle	1	50	19,425	64
10 per cent. Kerosene.	End	3	150	281,271	68
10 per cent. Kerosene	Middle and end	1	100	57,179	82
1 lb. Whale-oil Soap to 6 gal. water	End	1	75	77,171	43

From this it will be seen that 75 leaves bearing 49,000 scales were examined from the tree sprayed July 3, and that only 33 per cent. of the scales on this tree had been killed. In this case a first inspection was made ten days after the spray was applied, and a second, seven days later. The trees sprayed once July 11—at the middle of the hatching period—and from which 50 leaves bearing 19,000 scales were examined, showed a ratio of benefit of 64 per cent.; that is, 64 per cent. of the scales alive when the spray was applied, were dead a few hours later. In other words, by postponing the treatment from the 3d to the 11th of the month the effect of it had been nearly doubled. A similar but somewhat greater effect was produced by single treatments given July 19 and 20, when the greater part of the eggs were already hatched, 68 per cent. of the living scales among the 281,000 borne by the 150 leaves examined being thus killed. The most effective treatment was a double spraying, one application at the middle and the other about the end of the hatching period, which, as shown by an examination of 57,000 scales from 100 leaves of the tree so treated, killed 82 per cent. of the scales alive when the tree was sprayed. That is, the effect of the operation had been increased approximately 28 per cent. by the second spraying.

A comparison of the scales on the two surfaces of the leaves showed that the ratio of those killed on the lower surface was only 72 per cent. that of those killed on the upper surface. This was doubt-

less due in part to the fact that the upper surface of the leaf is more exposed to the spray than the under, and possibly also in part to the inferior vitality of the scales on the more exposed surface of the leaf. That there is really such a difference is shown by the difference in ratios of dead to living on the two leaf surfaces before the trees were sprayed. The general average of all the counts is 3.6 per cent. of dead on the upper surface of the leaf and 2 per cent. on the lower.

In the tree sprayed July 3 the effect on the scales on the upper and the lower parts of the top of the tree was brought into comparison by examining the scales on 25 leaves from each. Twenty-two per cent. of the scales on the upper leaves had been killed and 35 per cent. of those on the lower, the ratio of killed being more than half as great again for the lower leaves as for the upper. This is doubtless due, at least in part, to the greater and more prolonged effect produced on the lower leaves by the drip from the upper part of the top.

We may infer from these experiments that two sprayings with a 10 per cent. kerosene emulsion, one applied at the middle and the other at the end of the hatching period, separated, that is, by an interval of about ten days, will produce the maximum effect on the scale, and that they may be expected to destroy 80 per cent. or more of the insects then alive. It should be added that no harm to the tree was done by any of these treatments except a slight burning at the edges of the leaves of the tree which was twice sprayed. This appearance of injury was perhaps due to humid weather which followed the first treatment, delaying the evaporation of the kerosene. Two trees were treated July 11 with a 10 per cent. kerosene emulsion, at a time and place when rain was falling with a result to diminish by half the killing effect of the spray.

The cost of the 10 per cent. emulsion used in these experiments was 4.3 cents per gallon, and the trees were large enough to require three or four gallons each for a single treatment.

The whale-oil soap solution applied at the end of the hatching period had about two thirds the effect of the corresponding kerosene treatment, as shown by a comparison of the results of the data already given for the latter with those derived from an examination of 77,000 scales on 75 leaves taken from the tree treated with the former insecticide.

WINTER INSECTICIDE MEASURES.

Winter spraying, when the trees are bare, has the advantage that stronger insecticides may be used, and that less than half as

much liquid is needed to the tree. On the other hand, the scales are now larger and firmer and more resistant to the insecticide than in summer.

The extensive operations against this scale by the Superintendent of Lincoln Park during the winter of 1905-06 were followed by one of my assistants, Mr. E. O. G. Kelly, sent repeatedly to Chicago for this purpose. Nearly every tree and shrub in this park infested by the maple scale was sprayed under the immediate supervision of Mr. R. W. Braucher. Two thousand six hundred and seventy-three trees and 4456 shrubs were sprayed, nearly half the trees ranging from large to very large, and the remainder from small to medium. The materials used in this treatment were 4153 gallons of kerosene and 3074 pounds of soap, made up in 20,800 gallons of kerosene emulsion. The cost of the latter was approximately 2 cents a gallon. With the outfit used, a Fairbanks-Morse power sprayer with double "Vermorel" nozzles, it required, on an average, five minutes to spray each tree, or an hour for twelve trees. Eight men were employed with the outfit, making an average service of forty minutes of one man's time per tree. Six and seven tenths gallons of emulsion were applied to the average tree, at a total cost of 43 cents for both materials and labor.

In spraying operations, ladders and long canes were used in order that all parts of the larger trees might be reached by the spray. In the greater part of the work 19 and 20 per cent. emulsions of kerosene were applied. To make this up in 200-gallon lots, 20 gallons of water and 27 to 30 pounds of "Tak-a-nap" soap were placed in the mixing tub, and steam was introduced until the soap was dissolved and the solution was boiling hot. Forty gallons of kerosene were then slowly pumped into the tub, and the mixture was pumped back into itself until the kerosene no longer rose to the surface when the pumping ceased. The emulsion was finally diluted by adding hot water to make 200 gallons.

A part of the trees examined were sprayed between December 26 and January 5, and others January 11 and 13 and March 30. The effects of the spray were determined by comparing ratios of dead and living scales on trees which had been treated, with those from others examined at the same time which had received no treatment. A determination of the condition of the scales subsequent to treatment was a much more difficult matter at this season than during the summer. The dormant insects themselves were comparatively large and dense, and changes due to death were produced but slowly in the cold midwinter weather. From twenty-

seven to forty days actually intervened between the time of spraying and the time when the test inspections were made.

It will be sufficient to say, without entering into details, that a critical examination of 13,000 scales taken from 8 trees showed that 86 per cent. of them had been killed by a 19 per cent. emulsion; and an examination of 23,000 scales taken from 11 trees which had been treated with a 20 per cent. emulsion showed that 91 per cent. of these had been killed. Seven trees, two of which had been sprayed January 11 and five March 30 with emulsions containing from 19 to 24 per cent. of kerosene, were examined June 10, 49,000 scales in all being counted, with the result to show that in this case, also, 91 per cent. of those alive when the treatment was applied had been killed by the emulsion. The trees covered by these observations were soft maples, lindens, and honey-locusts, but as the percentages of benefit do not differ materially for these different species they need not be separately given. The following table summarizes these data.

When sprayed	Per cent. of kerosene	Date of count- ing	Scales counted	Percent. killed
December 26 to January 5	19	Feb. 1	12,703	86
January 11 to 13	20	Feb. 1-2	23,061	91
January 11 to 13 and March 30	19-24	June 10	48,395	91

INJURY TO TREES.

As one of the results of an examination of trees previously sprayed, made by my inspector June 11 to 13, he reported so serious a damage to some of the trees as to cast doubt on the safety of the kerosene spray. At Graceland Cemetery, for example, some soft maples had received during the winter an experimental treatment with a 25 per cent. kerosene emulsion, evidently prepared in the usual way, and all these trees were in a conspicuously poor condition, with foliage thin, pale, and shriveled, while that of unsprayed trees among them was heavy and dark green. Many of the trees in Lincoln Park on which an emulsion containing 19 or 20 per cent. of kerosene had been used, presented the appearance of a similar, although less serious, injury. A few, indeed, were dead, and dead branches were more numerous on others than usual.

After a study of the report of my own inspector, Mr. E. O. G. Kelly, on the condition of these trees last June, and a full and careful report on the same subject made to Superintendent Warder by Mr. R. W. Braucher, in charge of the spraying operation, and an examination of comparative photographs, made under Mr. Brauch-

er's direction, of trees of various species—some of which had been sprayed and others of which had not—it seems to me clear that many of these trees were already in a more or less enfeebled state owing to the light and sandy soil and other unfavorable conditions affecting their growth, that many treated trees had been further greatly weakened by heavy and continuous infestation by the maple scale, and that the consequences had been in some cases intensified by the action of the kerosene. This is especially suggested by the fact that trees seemingly most injured but not actually killed, presented the same general appearance—though in a more marked degree—as many of those which had not been sprayed at all. Precise and extensive experiments, the results of which may be brought into strict comparison, are needed to show the strength and the amount of the emulsion which it is safe to use under various conditions and on various kinds of trees.

In the meantime, in view of the fact that the thorough spraying of the top of a tall tree in winter requires a large amount of kerosene emulsion, much of which must fall to the earth, and the further well-known fact that fruit-trees may be severely injured, and even killed, by kerosene in the earth about their roots, it will be prudent to protect the ground where this insecticide is used by some impervious or absorbent covering, such as a sheet of canvas or a layer of straw, the latter afterwards to be removed. Kerosene will, in fact, remain effective in the ground for a surprising time, and this fact is the basis of one of its most important uses as a subterranean insecticide.* Thousands of fruit-trees have been destroyed within my own knowledge, by its careful use under the supervision of expert operators, where orchards were undergoing treatment for the San Jose scale.

Experiments already referred to, made at Denver, Col., by Mr. S. A. Johnson, resulted in a way to indicate that weaker emulsions than those used in Chicago may be depended on to destroy the maple scale, as shown by the following table.

Percentage of emulsion	10	12	12½	17	20	25	33	50
November, 1903	88		88		100			100
February, 1904	69	94		99		98	100	100

* The most notable instance of this persistence of kerosene in the earth which has come to my knowledge is reported to me by Professor T. J. Burrill, of the University of Illinois, who, in company with Prof. J. C. Blair, of the Horticultural Department, once lightly sponged the bark of a pear-tree with pure kerosene as an experiment. Nothing unusual was noticed the first year, but the second year the tree was seen to be unthrifty, and the third year it was dead. When dug up to learn the cause of its death, the odor of kerosene was still distinct and strong in the earth among its roots, and especially in the bark about the base of the trunk. The surplus which had run down the surface of the bark and sunk into the soil had remained all this time, acting, no doubt, continuously upon the roots and on the bark of the trunk in a way to kill the tree.

On the strength of these experiments Mr. Johnson recommends an emulsion one sixth of which is kerosene. Trees treated with an emulsion of this strength in the winter of 1904-05 were nearly free from scales the following July, and in January, 1906, only scattering specimens could be found. In view, however, of the difference in climate and the absence of data as to parasitism, these results should not be regarded as conclusive for Illinois.

INSECT ENEMIES.

It is to the insect enemies of the scale rather than to any human agency that the escape of our soft maple trees from complete destruction has hitherto been due. Probably the most effective enemy



FIG. 6. *Coccophagus lecanii*, adult chalcid parasite of the cottony maple scale. Length, less than $\frac{1}{16}$ inch. (J. B. Smith.)

is a minute black four-winged fly (*Coccophagus lecanii*, Fig. 6) which lays its eggs in the bodies of the young scales. The resulting larva lives as an internal parasite of the insect, develops to the adult, and emerges through a rounded hole cut in the back of the scale. Successive generations follow, and the scale population of a heavily infested tree may be almost completely destroyed in a single season by the parasite. Scales killed by it may be readily recognized by the hole in the back, and by their smaller size as compared with living individuals. Several other related species are known to infest this scale to a less degree.

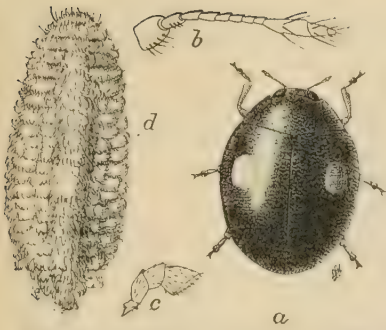


FIG. 7. A Ladybug, *Hyperaspis binotata*, enemy of cottony maple scale; *a*, adult; *d*, larva; *b*, *c*, antenna and palpus of adult. Adult about $\frac{1}{3}$ as long as *Chilocorus bivulnerus*, similarly colored; larva, white. (Sanders, U.S. Department of Agriculture.)

A conspicuous and very efficient enemy is a small hemispherical ladybug (*Hyperaspis binotata*, Fig. 7) about an eighth of an inch long, jet-black, with a small dark-red spot on each side of the middle. It is often seen on the leaves of infested trees and on plants beneath. The white thick-bodied larvæ of this species (Fig. 7, *d*), which feed on the eggs of the scale, may often be found buried in the egg-mass or crawling about on the twigs. The pupa of this ladybug is formed within the

cottony egg-mass, and soon changes to the adult. The beetles pass the winter wherever they may find shelter about the tree or on the ground beneath. The larger but similarly-colored "twice-stabbed ladybug" (*Chilocorus bivulnerus*, Fig. 8), with its black spiny larva, also destroys many maple scales.

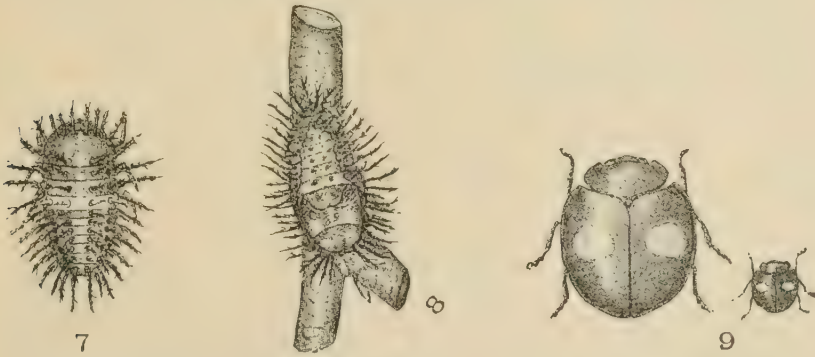


FIG. 8. A Ladybug, *Chilocorus bivulnerus*, larva, pupa, and adult, enemy of cottony maple scale. Natural size indicated at right; color black, adult with two red spots. (Comstock, U. S. Department of Agriculture.)

SUMMARY.

1. Injuries by the cottony maple scale are commonly periodical. A period of destructive abundance and following scarcity extends, on an average, over eight or ten years, the disappearance of the insect being apparently due in the main to depredations by its insect enemies.

2. A partial exception to the foregoing statement is presented by the existing outbreak in northeastern Illinois, and especially in Chicago, where the maple scale has continued injurious for at least six years, and gives no marked present evidence of a general decline in numbers.

3. The area injuriously infested by this insect in Illinois last year covers parts of at least fifteen counties, distributed throughout the state from the Wisconsin line to Marion county.

4. The chief food plant is the soft maple, but linden and box-elder are almost equally liable to infestation. The elm and the honey-locust are the principal other ornamental trees subject to serious injury.

5. There is but one generation of this insect each year. The females pass the winter partly grown on the twigs of trees, and produce eggs in late May or in June, according to the latitude and the weather of the season. These eggs hatch in June and July, the young insects establishing themselves for the summer on the leaves or twigs, from which they suck the sap. The males emerge as winged insects, and perish at the approach of winter. The females at that time collect on the twigs and smaller branches for hibernation.

6. The most useful insecticide is kerosene emulsion, which, if used in summer, should not contain more than 10, or possibly 12½, per cent. of kerosene, and, if used in winter, not more than 16 to 18 per cent. As a summer spray this emulsion must be used twice in succession, with a ten-day interval between sprayings. The first application must be made when about half the eggs are hatched, and the second at about the end of the hatching period. Two treatments with 10 per cent. kerosene, applied to badly infested trees in Chicago, the first July 11 and the second July 20, 1905, destroyed 82 per cent. of the scales; a single treatment July 11 destroyed 64 per cent.; and one July 19, 68 per cent. A similar treatment July 3, on the other hand, killed but 33 per cent. of the insects.

7. A single treatment in winter with a 19 or 20 per cent. emulsion destroyed more scales than two summer treatments with a 10 per cent. emulsion, the percentages of killed varying from 86 to 91 per cent.

8. Where large trees weakened by unfavorable conditions or by insect attack are treated with strong emulsions in winter, they are liable to injury by a penetration of the kerosene to the roots. Such trees should be protected, consequently, by covering the earth beneath the trees with sheets of canvas or layers of straw, or some similar absorbent substance.

9. Kerosene emulsion is made as follows: Dissolve one pound of common soap, or half a pound of whale-oil soap, in one gallon of water by boiling, remove from the fire, and add two gallons of kerosene. Then with a spray pump force the mixture back into itself for about five minutes, or until it presents the appearance of a thick cream and no longer separates on standing. This is the undiluted



PLATE V. SOFT MAPLE TREE SPRAYED WITH 20 PER CENT. KEROSENE EMULSION
JANUARY 19, AND PHOTOGRAPHED JUNE 23, 1906.
ORIGINALLY A SOUND TREE.



PLATE VI. SOFT MAPLE TREE SPRAYED WITH KEROSENE EMULSION JANUARY 18, AND PHOTOGRAPHED JUNE 23, 1906.
ORIGINALLY WEAK, WITH TRUNK AND LARGER LIMBS DECAYED AND HOLLOW.



PLATE VII. BOX-ELDER TREES, NOT SPRAYED. PHOTOGRAPHED JUNE 23. WEAK TREES WITH MANY DEAD BRANCHES.

emulsion. For a mixture containing 10 per cent. of kerosene, add seventeen gallons of water to the three gallons thus prepared. For an 18 per cent. kerosene emulsion, add eight gallons of water to the stock solution. Soft water is to be preferred.

10. The principal insect enemies of the cottony maple scale are minute winged parasites which lay their eggs within the bodies of the female parents; and hemispherical shining black ladybugs, each with two red spots on the back, the larvæ of which devour the eggs in spring within the cottony masses beneath the female body.

THE ELM TWIG-GIRDLER
OBEREÆ ULMICOLÆ CHITTENDEN.

In October, 1901, Mr. E. S. G. Titus, an assistant in my office at the time, was told at Decatur, Ill., by Mr. Frank Torrence, in charge of the parks of that town, that the common white or American elm-trees* there had been injured during the last three or four years by an amputation of great numbers of small twigs in June. Tufts of three to five or six leaves, each borne by a twig which had been cut squarely off, as if by a knife, would fall so thickly that in places the ground was nearly covered by them under the larger trees.

In consequence of a letter from Mr. E. A. Gastman, Superintendent of Schools at Decatur, written me May 10, 1902, reporting that this injury was just beginning for the season, Mr. Titus went to Decatur again on the 22d of May for a careful investigation of the subject. A considerable number of large elms in the city square (commonly called Central Park) were then being injured by some insect which was cutting off the young twigs, each bearing from two to seven fresh leaves. Other twigs, similarly injured but not yet detached, were found on a young elm-tree, beneath which were about twenty-five fallen leaf-clusters.

Among the insects noticed at the time was a species of *Oberœa* gnawing away the veins on the under side of the leaves. No eggs were found on or in the twigs at this visit, but three females and two males of this *Oberœa*, taken from an elm, were placed May 23 with twigs of that tree in a portable breeding-cage, carried about by Mr. Titus while he was traveling for the office. Two eggs found in a fresh elm twig in this breeding-cage May 24, four more May 28, and two May 29, together with a newly hatched larva found in one of these twigs May 30, made plain the cause of the injury.

Later visits to Decatur by Mr. Titus, by Mr. F. M. Webster and by Mr. E. P. Taylor, together with breeding-cage observations and field and insectary experiments, have given me the materials for a fairly full account of this insect, especially interesting because of its power of injury to our most important shade tree, and also because it has lately been found infesting the cherry, and, in one case, the peach.

**Ulmus americana*.

The only previous mention of this species is contained in an article prepared at my request by Mr. Webster, (in my office at the time,) and published in the Bulletin of the Illinois State Laboratory of Natural History* in February, 1904. In this article the species is described by Chittenden under the name of *Oberca ulmicola*, and the main facts are reported so far as observed up to that time.

RECOGNITION OF THE INJURY.

The presence of this insect may be suspected when the tips of small twigs of the elm, each bearing a few fresh leaves and cut squarely off at the base, fall from the trees between May 20 and June 15. A careful examination of the stubs remaining on the tree where these twigs have been cut off, will show a narrow encircling groove or girdle cut through the bark at two inches or less from the blunt end, and a small L-shaped slit between this girdle and the end of the stub. On other twigs which have not yet lost their tips, two girdling grooves may sometimes be seen, about two inches apart, with the L-shaped slit between them, and in this case the tip of the twig may be readily broken off at the groove nearest the end.

If a tree has been considerably infested the preceding year, dead stubs, single or clustered, may be seen here and there on the branches, with younger twigs springing up among them and still alive. Repeated injuries of this description, year after year, give the tree a scrubby and unwholesome look, and may even kill it eventually, after forcing it to put forth new twigs repeatedly, as the growth of the preceding season is destroyed.

The insect doing this injury is a slender, cylindrical, hard-shelled beetle, about half an inch long, with head and body black above, except the thorax, which is yellow with two round black spots near the middle. The color beneath is mainly yellow. (Pl. VIII., Fig. *a*.) The female lays her eggs, one in a place, usually under a triangular flap of bark made by the intersection of the lines of an L-shaped slit.

The slender larva of this beetle (Fig. *c*) lives within the injured twigs, which it burrows lengthwise, pushing its excrement out through small round holes made in the bark for the purpose. It is about half an inch long when full grown, light straw-colored, a little darker at the ends. The pupa (Fig. *d*) is formed in the larval burrow.

*Vol. VII., pp. 1-13.

NATURE AND EXTENT OF THE INJURY.

Under a badly infested tree, hundreds of fallen twigs, bearing four to six leaves each, may be found in May and June. Sometimes twigs are cut off not more than a half or three quarters of an inch long, each bearing only a single leaf; and occasionally those amputated are a foot long, with a dozen leaves or more.

When the beetles become superabundant, a female frequently girdles the stub of a twig below the point where an egg has been previously placed by another beetle, thus causing the part containing the first egg, or the young larva hatching from it, to fall to the ground. She then places her own egg in this second stub. Five per cent. of the twigs collected May 29, 1903, had been used a second time in this manner. Later in the season these amputations were sometimes repeated five or six times on the same twig.

If the tree is very heavily attacked, the fallen leaves may nearly cover the ground in early June. Under eighteen trees in the city square of Decatur, there were picked up on the 7th and 8th of June, 1905, 11,986 twigs, measuring six bushels when closely packed. Seven hundred were collected beneath one tree on the 4th of June.

The effect on the trees is to destroy the young twigs put forth prior to the middle of June, and this injury, continuing year after year, results in bunches of dead stubs distributed all through the top. The trees become stunted, scraggy, and misshapen, with the leaves growing in tufts on the larger limbs. The younger trees lose their spreading habit, and grow upright with narrow ragged tops. The larger ones are less affected, but are injured in appearance by the loss of foliage, and by clusters of dead stubbed twigs seen everywhere through the tops. A tree in Central Park, about forty feet high, had been so seriously injured in 1904 that by May 3 of the following year only a few leaves had appeared, although uninjured elms were thickly covered with half-grown foliage. Large branches of this tree, which had previously sent out many clusters of secondary twigs, were now dead. On one branch, about the thickness of a finger, killed by girdlers the preceding year, nineteen truncated stubs were counted within a length of fourteen inches. Another tree, thirty-five feet high, was so injured that it would probably die before another season. Only a few leaves had appeared by the 5th of May, and these were in the center and at the top.

In Decatur, where this insect was first discovered and has been chiefly studied by us, the elms of the greater part of the city were infested in 1905, as was shown by a general survey made by Mr. Taylor in May and June. The infestation had not yet reached Fair-

view Park, nor the grounds of Millikin University, in the outskirts of the town. The slow spread of the beetles was shown, not only by their destructive abundance in some parts of this town and their virtual absence in others, but also by the fact that of trees standing side by side some showed scarcely a trace of injury while others were badly damaged. The beetles can fly vigorously, and were sometimes seen on the wing; but they seem to lack the dispersal instinct—a fact the more remarkable because they are extremely intolerant of each other's company, both males and females attacking each other ferociously and devouring one another so readily that they can not be kept together in confinement.

The injury to the elm begins late in May. On the 23d of that month in 1902 a few fallen twigs bearing fresh leaves were first noticed at Decatur, and others recently girdled but not yet fallen were seen on the trees. It is most abundant early in June, commonly from the 1st to the 5th, and may continue to the 24th of that month, after which date, in 1905, it was practically over for the season. It was noticed by Mr. Titus that rains and cool weather stopped the work of the beetles, sometimes for two or three days at a time.

Besides its injuries to the common American elm (*Ulmus americana*), this insect was seen at Decatur infesting, in the same way, cherry-trees, both sweet and sour, and it was once found in a peach-tree at the same place. Red elms, on the other hand, growing among badly infested white elm-trees, showed no traces of the attack, and raspberry plants, liable to infestation by another species of the genus, were absolutely refused by beetles of this species kept in confinement and offered no other food.

Experiments made by Mr. Titus in May, 1903, showed that this beetle will not breed in either dogwood stems or raspberry canes. For example, three pairs of specimens, male and female, which had been bred at various dates from elm twigs, were placed May 20 on a growing raspberry plant out-of-doors under a bell jar. The beetles were noticed pairing, but May 29 all were dead, leaving no trace of eggs or preparations for their deposit on the plants, and no evidence of any attempt to feed on the leaves except a little gnawing of the midrib of one leaf. When beetles were shut up under glass with twigs and leaves of the elm the insects fed and bred quite as freely as if at large.

LIFE HISTORY AND HABITS.

There is but one brood of this insect in a year, and it passes the winter as a larva in the stubbed twigs remaining on the tree. It pupates from the middle of April to the last of May, within the larval burrow, the outer end of which is closed by a wad of chewed wood, and here also the pupa changes to the adult, beginning about May 10. The beetle does not eat its way out of the burrow, but escapes by pushing out the terminal plug of the hollowed-out twig. Pairing and egg-laying follow, from about May 20 to the 10th of June, accompanied by the amputation of twigs as already noticed. The beetles, male and female, die soon after the eggs are laid, and all are gone by the last of June.

Mode of Oviposition.—It was observed by Mr. Titus in 1902 that the female beetle first girdles the twig by cutting with her jaws a groove entirely around it so deep that the twig is readily broken off. Below this she then cuts a longitudinal slit about an eighth to a fifth of an inch in length through the bark but not into the wood, and at the lower end of this she makes a shorter transverse slit, sometimes to the right and sometimes to the left, also merely through the bark. She now pushes the tip of her abdomen under the bark at the angle formed by the two slits thus made, and places her egg under the flap, where it can easily be detected by the slight elevation thus caused. She next retreats still further towards the base of the twig, and here girdles it a second time, now merely cutting through the bark, thus deadening the part beyond the girdle without causing it to fall. The effect of this complicated operation is to provide a safe lodgment for the egg, and so to arrest the growth of the twig that the egg shall not be crushed, the young larva finding, when it hatches, living wood at once available for its food.

While the distance between girdle marks may be an inch or more, it averages about five eighths of an inch, and the egg-slits are made on the middle third of the space between the girdles. Where the beetles are superabundant, this operation may be performed several times upon the same twig, by females unable to find each her separate branch for the deposit of her eggs. The result must be a serious loss of eggs, or of young larvae hatching from them, since only one of the latter can continue and mature in a single twig. Although as many as eight or ten girdles may be found on a twig in June, never more than a single larva occurs in each the following spring.

The Egg.—Our earliest date for the eggs is May 22 (1903), and they have been found in twigs of the elm and the other trees infested, at frequent intervals from that date to June 24. As the girdling of twigs was at its height May 29, 1903, and has been noticed as late as June 10, it is probable that oviposition may continue at least to the latter date.

The Larva.—The larvæ of the preceding year are found in the stubs of twigs on the trees in spring, but, according to our observations, all have pupated and emerged, as a rule, before the young of the following brood begin to hatch. Our earliest date for the hatching of the larvæ is June 13, and the latest is about the 24th of June. The average length at the latter date is about a sixth of an inch, which is nearly a third the length of the full-grown larva. July 21, 1905, thirteen young larvæ measured from 4 to 11.5 mm. (.16 to .46 of an inch), with an average of 7 mm. (.28 of an inch), varying, that is, from one third size to nearly full grown, and averaging about half their final length. The burrows of several specimens varied in length, at this time, from 1 inch to 2½ inches.

According to the observations of Mr. Titus, the young larva, upon first breaking the shell of the egg, begins immediately to gnaw a channel downward just beneath the bark, and turns inwards towards the center when it is about half way out of the shell. When it has thus freed itself from the egg it apparently backs up into the shell cavity and cuts a small circular hole in the bark as a vent for its excrement, which, up to this time, has been left in the cavity originally containing the egg. It then burrows down the center of the twig, making additional holes to the surface from one to two inches apart as it progresses.

In small twigs, almost the whole interior is thus eaten out (Pl. VIII., Fig. *b.*), leaving only the shriveled bark and a very thin layer of wood; and occasionally this inner cavity reaches nearly to the truncated tip of the twig, as if the borer had worked first in a direction opposite to its usual course. From the progress of a larva down its twig, it appeared that its average rate from June 23 to August 31 was a little less than a fifth of an inch a day ($4\frac{1}{4}$ mm.), but water-sprouts nearly two feet long were seen in September hollowed out to the base by a single larva. When a burrow passes the point of origin of a lateral twig, the base of this is sometimes eaten out and used as a place of deposit for the larval excrement. Sometimes twigs passed by the larva in its downward descent are successively cut off from within, the insect eating a circular groove through the wood, so weakening the twig that it presently breaks

off. In one instance, followed in the insectary from the 12th of July, 1905, to the 12th of the following June, a larva thus amputated eight lateral twigs.

The cavity made in the twig, although apparently a close fit for the larva, is nevertheless large enough to permit it to turn upon itself and to move in either direction. Of twenty-three larvæ examined May 22, eleven were lying with heads towards the tip of the twig and twelve towards the base. It frequently happens, where a tree is as heavily infested as were many of those in Decatur, that eggs will be laid in several small spurs all leading to a larger twig in which all the larvæ which live must finally meet. A destructive competition must follow, since each infested twig harbors, finally, only a single surviving borer.

When a larva passes down a smaller twig to a larger branch, it burrows only in the newer wood immediately beneath the bark. In such a branch it commonly takes a winding course, its track in one instance even doubling back upon itself for a considerable distance.

The larvæ, in various stages of growth, hibernate in their burrows and finish their growth the following spring. May 22, for example, they were found by Mr. Webster in the wood of the preceding year, still burrowing downwards, with the effect to kill the lateral shoots as they passed.

Pupation occurs within the burrow, in a cavity shut off in both directions by a firm plug of mingled woody fiber and excrement. The beetle makes its way out of this cavity by pushing out the plug at the end of the twig, and never, according to our numerous insectary observations, by cutting through the wall of its cell.

As an example of the observations from which these biological data are derived, the following abstract from the insectary notes of one of the 1905 experiments may be given. They were written alternately by R. M. Webster and J. J. Davis, entomological students in the University of Illinois, serving as insectary assistants at the time.

On the 22d of July twigs of the elm containing *Oberca* larvæ, sent by Mr. Taylor from Decatur, were transferred to living elms at the insectary, either by carefully grafting the infested twigs into those of a growing tree or by hollowing out in the living twigs artificial cavities in which *Oberca* larvæ were separately placed. By the 25th of July evidence of the activity of these transferred larvæ was seen in the wood dust on the infested twigs; and by the 1st of August one of the larvæ had passed the graft from its original twig into the living stub on the tree, and had made a hole for the wood dust an inch beyond this point.

August 8 one of the larvæ had cut off a lateral twig by burrowing into its base for about 2 mm. and then gnawing a circular groove from within. At this time four of the experimental larvæ were alive. On August 11 a second twig two and a half inches from the graft was similarly cut off by the larva within, and on the 14th still another on the opposite side of the branch, and on the 16th a fourth. The dust holes made by these larvæ were from two to three inches apart. On the 24th of August the fifth lateral twig was girdled five inches down the branch from the graft. On the 29th and 30th, the sixth and seventh twigs were cut off, these two being nearly an inch and a half apart. A larva which was forced by grafting to work downward through a twig an eighth of an inch in diameter, entered at its base a branch two fifths of an inch thick, and continued its excavations just beneath the bark.

By the 5th of September only two of the larvæ remained alive, and by the 20th one of them had burrowed a distance of ten and a half inches, since its start July 12,—an average of .15 of an inch a day. On the 25th of September it was noticed that this larva had shortened its burrowed twig by cutting it off from within at the place where its last dust vent had been made, and on the 2d of October the open end of the burrow was found plugged with wood dust, doubtless in preparation for hibernation. On the 14th of May one of these twigs was opened and the *Oberca* pupa was found within at the upper end of the burrow. Transferred to a breeding-cage, the beetle emerged May 18. The other specimen, still a living larva March 13, was used in an experiment with a carnivorous larva of *Cymatodera balteata*, one of the enemies of this insect to be described under another head.

The Pupa.—Our earliest date for the appearance of the pupa is April 16 (1903) and the latest for its occurrence is May 22. On the other hand, the earliest date at which we have seen the beetle emerge is the 10th of May, giving us thus, by inference, a period of about three weeks in the pupa state, an estimate borne out by individual records from my insectary notes. From a pupa formed April 17, for example, the beetle appeared on the 12th of May—a period of 25 days; in another instance a pupa formed April 16 yielded the beetle the 13th of May—27 days; and in four others the pupal period varied from 20 to 29 days. In one case of seemingly delayed pupation this period extended only from May 3 to May 19. The average of all our recorded observations is $23\frac{1}{2}$ days.

The dates of the pupal period are especially important, since one of the readiest methods of controlling this pest is to clip off, by

means of pruning-shears, the infested twigs at the time when they contain the pupæ. In 1905 the greater part of the larvæ had pupated by the 3d of May, at which time, among 19 specimens, 18 were pupæ and only 1 was a living larva. An observation made on the 5th of May showed this to be about the height of the pupal season, since all specimens seen were pupæ except one. May 22, on the other hand, of 20 specimens, 18 were adults, 1 was a pupa, and 1 a larva not yet transformed. The last was probably parasitized. From observations of 1905 directed especially to that point, Mr. Taylor concludes that pupation begins, as a rule, with the beginning of the ripening of the seeds of the elm, and that the pupa is almost always to be found within two inches of the tip of the infested twig. In the only exception noticed it was about $2\frac{3}{4}$ inches from the end. It is normally formed with its head towards the tip of the twig. In the only case seen to the contrary, the beetle forming within the pupal chamber had perished without coming out.

The Beetle.—Our earliest date for the recently formed beetle is May 10, at which date one appeared in a breeding-cage and three were taken on trees at Decatur. As pupæ were found until May 22, the period of transformation is apparently about two weeks. The sexes were seen pairing at various dates between May 21 and June 7. Adults began to die on the 29th of May, and the latest were seen alive June 11. The entire life of the insect in the beetle stage is consequently about a month.

The beetles feed on the veins of the leaves, gnawing these away from the under side, thus sometimes making longitudinal slits through the thickness of the leaf (Pl. VIII., Fig. c). This injury at Decatur was easily seen from the ground on looking upward through badly infested trees. In breeding-cages, where the food was comparatively scarce, the leaves were thus riddled and killed, the petioles were eaten, and even the soft tip of the twig was gnawed into or eaten away.

Although not readily provoked to take wing, the adults are of active habit, and have a good power of flight. Their slow dispersal is not due to any lack of locomotive power, but to what, in view of the destructive consequences to the species, we must look upon as an aberration of instinct. Though no trace of the beetles was found in some parts of Decatur where elms were abundant, they were so numerous in other parts of the town that a large percentage of their larvæ could not mature in the infested trees. Several females were girdling the same twig and depositing their eggs there successively although there was an abundance of fresh material a little distance

away. Twigs were found by Webster in which eggs had been laid as many as eight separate times, with the usual number of girdlings in each case, with the necessary consequence that only one of the larvæ hatching could survive. "Late in May," he says, "I began to find sections of amputated twigs on the ground underneath the trees, which showed plainly that this amputation was not the result of a first visit of a female intent on oviposition. Ordinarily, the tip of the twig is severed far enough back to include from two to four or five leaves, and this amputated portion is free from egg or larva. But I now began to find, scattered under the infested trees, pieces of twigs which had been cut off at both ends, and those freshly dropped contained in most cases either an egg or a newly hatched larva, while in the older, withered ones there was more often a very young larva, dead. As the season of oviposition advanced, these secondary amputations, repeated perhaps five or six times on the same twig, became more numerous, and an examination of the trees disclosed the fact that nearly every twig contained at least one egg or larva, and that some of them contained several. For those females that had yet to oviposit, there were no twigs not preoccupied, and fully five per cent. of the amputated pieces on the ground contained a larva or an egg. It became clear that the mortality resulting from this repeated oviposition and amputation was greater than that from all other causes combined."*

Another seeming error of instinct is the senseless hostility which these beetles exhibit towards each other, if one may judge by their conduct in confinement. "If a male and female were confined at all closely," says Webster, "they would instantly attack each other with such ferocity that within a few moments they would be rolling helplessly about among fragments of legs and antennæ, only the basal portions of these remaining attached to their bodies. It was found wholly impossible to transport living individuals without giving them ample quarters, and I was finally forced to give each a box or vial to itself."†

DISTRIBUTION.

Although the first and much the most serious infestation was found at Decatur, in Macon county, elms at Henry, Princeton, Aurora, and Rock Island were found by Mr. Webster containing *Oberca* larvæ in August, 1903. It was not certain, however, that these belonged to our species, since *Oberca tripunctata* likewise in-

*Bull. Ill. State Lab. Nat. Hist., Vol. VII., Art. I., pp. 10 and 11.

†Ibid., p. 10.

feasts the elm. The same may be said of a trifling injury to white elms noticed in Urbana in June, 1905, where tufts of leaves borne on the tips of twigs neatly cut off after the manner of the elm twig-girdler were occasionally picked up from the grass. Some of the leaves were also eaten along the veins after the manner of these beetles.

There can be no doubt, however, that our species is responsible for a serious injury to white elms detected at Moweaqua, in Shelby county, Ill., in May, 1905, by Mr. W. N. Dawson, a commercial traveler of Decatur. Noticing accounts of the Decatur observations in the local press, he wrote to the office that he had discovered the work of the elm twig-girdler upon trees surrounding the Illinois Central station at Moweaqua, inclosing with his letter some of the girdled twigs. When Mr. Taylor visited this place, May 25, adults of *Oberca ulmicola* were still within their pupal cells, from which they were preparing to escape by pushing out the plug at the end. From under a single elm-tree about sixty feet in height, near the railway station, one hundred and sixteen girdled twigs were picked up, and nine other elms, all very large, were found infested. It is very probable, in fact, that this species is generally distributed, and that its discovery at Decatur was due to its extraordinary and abnormal abundance there.

NATURAL CHECKS ON MULTIPLICATION.

Two insect species were found at Decatur preying on the elm twig-girdler, one a minute hymenopterous parasite, *Euderus lividus*, and the other a predaceous grub of a beetle, *Cymatodera balteata*. The larvæ of both these insects devour the *Oberca* larva in its burrow. Of seventy-two *Oberca* larvæ contained in elm twigs from Decatur and examined July 22, fifteen had been destroyed by the hymenopterous parasite, which was present in the burrow as a pupa in twelve cases and as a full-grown larva in three. The predaceous larva of the beetle was repeatedly found in burrowed elm twigs along with dead or mutilated larvæ of *Oberca*, and living *Oberca* larvæ exposed to its attack in the insectary were promptly devoured by it.

Euderus lividus Ashmead.

On splitting twigs burrowed by *Oberca*, Mr. Taylor frequently found, in late June or in July, the young larva dead or wanting, and in its place a small white larva, or a dusky pupa 2-3 mm. long according to sex, the females being the larger. These pupæ yielded,

in breeding-cages, the adults of a chalcid,—*Euderus lividus*, as determined for us by Mr. Ashmead. A pupa obtained July 22 gave the adult July 28, and a larva found on the first date had recently pupated August 1, and had changed to the adult by August 7. The species is recorded by Dr. Nason from northern Illinois, and by Mr. Ashmead from Florida.

Description of Adult.—Length about 2–3 mm. Rather slender, abdomen slender, conically produced in female. Color dark metallic blue, dorsum of thorax greenish, antennæ black, 10-jointed, white-hairy; tarsi white except last joint, which is dark brownish. Thorax finely reticulate, with a network of raised lines; marginal vein long, submarginal and postmarginal rather short, stigmal short, the knob short-petiolate.

Description of Pupa.—Length of male, about 2 mm., of female, 2.5–3 mm.; width, .6–.8 mm. Color light fuscous brown, darkening as adults mature. Abdomen of male with last three segments rapidly tapering to a blunt point, these segments often slightly darker than those preceding, and but slightly longer; abdomen of female with last three segments acuminate tapering, the sixth slightly longer than the fifth, seventh half as long again as the sixth, eighth narrow, twice as long as sixth. Ovipositor extended forwards on the median ventral line to base of sixth segment. Posterior legs nearly or quite attaining base of sixth segment.

Cymatodera balteata Leconte.

The predaceous larva of this beetle is about a fourth of an inch long, plump, elongate-oblong, with a projecting, strongly flattened head. The body is somewhat hairy, flattened and whitish beneath, dusky pink above changing to black in alcohol. The back is marked with a conspicuous confluent row on each side, next the margin, of large round whitish spots, each with a dark center connected with the dusky color of the back; and along the side is a dusky line just above the ventral surface. The last segment is chitinous, and bears at its tip a pair of slightly divergent strong recurved hooks.

These larvæ are very active, and are capable of burrowing into the infested twig in search of their prey. A larva taken May 3 and kept without food pupated between May 29 and June 19, and was an adult in the burrow June 26. Another taken the 5th of May and supplied with food after the 9th, continued in the larval stage over the following winter. March 13 it burrowed into an infested elm twig, entering at the plugged end, and devoured the *Oberca* larva

within, and May 8 it was still unchanged in the *Oberca* burrow. By June 11, however, it had transformed to the adult, and made its exit from the twig on the 19th of that month. The adult has been captured by us repeatedly in Illinois from late July into September. The species is listed from New Jersey, and is said by Horn to occur from the Middle States westward to Kansas and Texas.

Description of Larva.—Moderately elongate with nearly parallel sides, but tapering rapidly at each end. The length of the largest specimen, 8 mm.; its breadth, 2 mm. Pale yellowish, marked with dusky pink becoming purplish in alcohol, and tinged more or less with chestnut at the ends. Skin soft, smooth, sparsely covered above and below with pale hairs. The head about as long as its breadth at the antennæ, black, varied with dark chestnut above and below. The antennæ, labrum, and inferior mouth-parts pale; the mandibles black, broad, acute, a tooth or tubercle on the inner edge near the base; the anterior edge of the labrum broadly concave. Ocelli, three, equal, distance between them about half their diameters. Hairs of the head arising from pale dots. Prothorax with large black semicircular dorsal shield, narrow pale margins, and a pale median line which broadens and opens out widely behind. Suture between it and the head variable, blackish. The two remaining thoracic segments with black lateral margins and a U-shaped discal patch; also a dark W-shaped mark in front of this; some oblique lines on the mesothorax, and an irregular posterior border of black on the metathorax. Thoracic legs rather short and stout, dark dorsally, the femur with a pale annulus near the middle; coxal sutures ferruginous or blackish. Abdomen 9-jointed, the segments, except the last, about four to six times broader than long, gradually lengthening from before backwards. The lateral margins, except those of the last segment, dark. A broad median dark dorsal stripe about as wide as the head, and slightly more than half as wide as the body, ending on the base of the last segment, interrupted at the sutures and sometimes divided by a pale median line. Between this stripe and the lateral margin, a subdorsal stripe or confluent line of pale rounded spots, one for each segment, each with a black central patch connected at the posterior margin of the segment with the dorsal stripe; beneath yellowish except for a few purplish dots variably evident on the hind margins of the posterior segments. Last segment greenish beneath, with a prominent anal tubercle and a chitinous fork at the tip. Dorsal surface with a round black patch on the apical two thirds. The anal fork is dark chestnut or black, the outer sides of its prongs about parallel, but

divided within by a notch intermediate in form between a V and a U. Apical part of each prong acute, curved ventrally upward and a trifle forward at tip.

Described from three examples in alcohol.

PROTECTIVE MEASURES.

The fact that the elm twig-girdler is deficient in the instinct of dispersal, and hence remains to breed in the twigs of the tree in which it originated, makes it a dangerous insect, but at the same time exposes it to wholesale destruction by artificial measures easily applied to the small number of trees which it is likely to infest to a dangerous degree. Its feeding habits and its life history suggest two practicable methods of destroying it. Since the beetle feeds on the leaves of the elm, it may be poisoned by arsenical insecticides sprayed on the leaves during the last week in May; or, since it completes its transformations in its burrow, it may be killed in the larval or pupal stage by trimming off and burning the infested twigs in spring at any time preceding the middle of May. A combination of these operations, first cutting off the visibly infested twigs and then spraying the tree to destroy any beetles coming in from outside or emerging from twigs overlooked, would be a doubly effective safeguard against further injury. Both these methods were tested at Decatur with encouraging results.

Infested twigs are easily recognized in spring by their stubbed ends, left by the breaking off of the twig at the place where the outer girdle has been made by the female before depositing her eggs. Twigs containing the insects are commonly a fourth of an inch or less in diameter, and the pupa is formed almost invariably within two inches of the end of the stub. By a practical test of the trimming method, made in Decatur May 5, it was found that badly injured trees were easily cleared of infested twigs, which were readily seen among the scanty foliage, but that it was more difficult to make sure of a thorough operation where the injury was less and the foliage more abundant. Eighteen trees ten to thirty feet high were pruned by Mr. Taylor, with one assistant, in an average time of half an hour to the tree, using a 14-foot step-ladder, a pruning-saw, and a pair of pruning-shears with handles eight and twelve feet long. No way was found, however, to clear by this means trees more than thirty feet in height, and for these the spraying method must be the main dependence.

In Mr. Taylor's report of an extensive spraying experiment made at Decatur May 23, fifteen trees averaging about twenty-one

feet in height, and treated with arsenate of lead, are comparable with twelve trees, all less than thirty feet high, left untreated as a check. The treated trees were sprayed twice, once May 23 and again June 6. Ten were sprayed with the arsenate of lead of the strength usual in orchard practice—12½ ounces of sugar of lead and 5 ounces of arsenate of soda, dissolved in 50 gallons of water. Five of the trees were sprayed with a solution of twice this strength, the solid ingredients being dissolved in 25 gallons of water. All twigs which fell from these various lots, both checks and experimental trees, were gathered and counted daily, with the general result that the check trees dropped in all 1148 twigs, or an average of 96 per tree; those treated with the weaker spray dropped 420 twigs, an average of 43 per tree; and those treated with the stronger spray dropped 65 twigs,—an average of 13 per tree. In other words, the weaker spray preserved 55 per cent. of the twigs which would otherwise have fallen, and the stronger spray, 85 per cent.

Only one of the largest trees was sprayed under conditions to serve the purposes of an experiment. This tree was about seventy-five feet high, and from it fell only 95 twigs in all, while eight untreated trees, averaging sixty-four feet in height, gave a total of 12,721 fallen twigs, an average of 1490 per tree. The number varied under the different trees from 937 to 2029. The ratio of benefit on this large tree thus seems to have been 94 per cent. Except for the difficulty and labor of spraying large shade trees, this insecticide treatment was as satisfactory as could be expected of any like operation.

When the insecticide was first applied there was but little wind, and the weather was fair. A heavy rain with wind followed the second spraying, and doubtless diminished somewhat its effect. Twigs fell in considerable numbers until the 28th of June, after which but few were collected.

In preparing the arsenate of lead, the sugar of lead and the arsenate of soda are separately dissolved, and poured, in succession, into a quantity of water sufficient to reduce the solutions to the strength desired. In the Decatur experiment a Morrill and Morley "Éclipse" hand-pump No. 6 was used, with two 35-foot lengths of hose and 12-foot extension poles. A 14-foot step-ladder was sufficient to give access to the tops of trees of medium size, while for those from sixty to eighty feet high, 65-foot extension ladders were used—the property of the Decatur Fire Department. The amount of the insecticide required, varied from five to ten gallons for the small and medium trees to forty gallons for the largest



a



c



d



b



e

PLATE VIII

THE ELM TWIG-GIRDLER, *Oberea ulmicola*: a—adult beetle, length nearly $\frac{1}{2}$ inch; b—egg enlarged, and others in position under bark of twigs; c—larva, d—pupa, both enlarged; e—elm leaves, showing leaf veins eaten out by beetle in feeding.

elm treated, and the time required for the spraying varied similarly from about ten minutes to an hour. The force necessary was three men and a boy, the latter to keep the solution constantly stirred during the spraying.

The most suitable time for the first spraying is obviously that just preceding the appearance of the adult beetles on the leaves. May 23, when this experiment was begun, 5 per cent. of the insects in the twigs were still larvæ, another 5 per cent. were pupæ, and 90 per cent. were adults about to emerge. It was estimated by Mr. Taylor that possibly 5 or 10 per cent. of the beetles had already come out of their burrows and were feeding on the leaves, although very few, if any, twigs had fallen as yet in consequence of the girdling operations of the female beetles.

DESCRIPTION.

(Plate VIII.)

Adult.—Form slender. Head, antennæ, and elytra black, with gray pubescence, becoming long and dense on the head, nearly obscuring the punctures, and darker plumbeous-gray on the thorax. Antennæ slender, long, five sixths of the length of the entire insect. Head somewhat feebly and sparsely punctate, with strongly defined median line, especially in the posterior portion. Thorax yellow, callosities black, occasionally with a smaller black antescutellar spot on each side; just above the leg there is usually another variable black spot, either smaller or much larger than the others. Elytra with basal portion on each side of and including the scutellum, yellow, occasionally with a longitudinal yellow streak on each elytron, extending from the base nearly to the apex, which is emarginate and sub-bidentate; the surface comparatively sparsely and feebly punctate. Epipleuræ yellow. Ventral surface usually yellow, but occasionally with a portion of the thorax and of the second and third abdominal segments and less frequently the first and last segments black. Punctuation very shallow, nearly obsolete on abdominal segments. Proximal portion of legs yellow, distal portion black.

Length, 9–13 mm.; width, 1.2–2.0 mm. Average length, 12 mm.; width, 1.9 mm.

Egg.—Length, 3 mm.; width, 0.6 mm.; slightly reniform, of a creamy white color, without perceivable reticulations.

Larva.—Length, 14 mm. Head much smaller than thoracic segments, body decreasing in width posteriorly with moderate uniformity to the eighth segment, which is considerably smaller, the anal still more reduced; body light straw-color, the two posterior

segments lighter; head anteriorly dark brown, posteriorly the color of the body, mandibles darker than anterior portion of head. Cervical shield brownish yellow, anterior surface smooth polished, terminating posteriorly in a slightly raised transverse ridge. The apical declivity is shagreened, more finely posteriorly and centrally; narrow median dorsal area whiter; the lateral oblique, sinuate grooves darker. In front of the shagreened area are a few short erect hairs, with larger ones placed laterally on this segment. On the next segment there are but two lateral hairs on each side, and none on other segments until the eleventh, which has a single stout bristle on each side considerably above the margin, and a transverse row of hairs along the posterior margin. The anal segment has a considerable number of long curved hairs along the lateral and posterior areas. The lateral margins of each of the abdominal segments, just below the spiracles, have an inflated appearance, and segments three to ten inclusive are strongly sculptured, especially on the dorsal surface, by transverse, tubercular, flattened ridges which are minutely shagreened. The sculpture of these is clearly shown in Plate VIII., Fig. c. The lateral inflations, with deep intervening constrictions, give the larva when extended a somewhat moniliform aspect.

Pupa.—Length, 13 mm.; color uniformly light yellow; head with nearly triangular impressed area between the bases of the antennæ, on each side of which are a pair of closely set hairs. There are two clusters of minute spinules on the clypeus. The antennæ, being abruptly bent downward, give the head a decidedly square appearance. They extend backward to just beyond the middle femora, where they turn forward along and outside of the anterior and middle legs, the posterior pair of legs being folded under the wings. There is a minute, robust, hooked spine on the marginal ridge of each of the abdominal segments except the terminal, the hooks being reversed; there is also on each of these segments a transverse dorsal elevation armed with irregularly placed minute stout spines. The terminal segment is provided with a number of long hairs.

ON THE LIFE HISTORY, HABITS, AND ECONOMIC RELATIONS OF THE WHITE-GRUBS AND MAY-BEETLES (*LACHNOSTERNA*).

The insects generally known as white-grubs are the young, or larvæ, of the large brown beetles commonly called "June-bugs" or May-beetles. For a practical knowledge of these destructive insects it is necessary that we should know the various species of them which do serious injury to agricultural and to horticultural crops; the life histories of all these species; their relative numbers in different parts of the state in different years and in different periods of years; their food, both as grubs and as adult beetles, including their common preferences where several kinds of food are available to them; their significant habits, especially those of reproduction; their relations to variety of weather and to seasonal change; their modes, times, and places of hibernation; the range of their daily movements and of their movements of migration and dispersal; their enemies, their diseases—especially those of a contagious character, and the other natural checks on their multiplication; their relation to varieties of soil, to its physical condition, its moisture, and its exposure to the sun; their relation to varieties of the subsoil also; the effects on their continuance and increase, of various agricultural operations and kinds of farm management; and their own effects, under varying conditions, on the several kinds of crops subject to injury by them. Finally, the whole field of preventive and remedial measures of a more or less artificial character must be thoroughly explored, including the results of practical experiments on the scale of actual farm management.

The subject is made especially difficult and complicated by several facts and circumstances. There are many species of these insects recognizable in the beetle stage but seemingly not distinguishable as larvæ; hence one frequently can not tell what kind of grub he is dealing with until he has reared specimens to the adult. The life history of these insects has a prolonged cycle, probably of three years, but just how many is not definitely known, and life histories can be completed only by keeping specimens alive, under more or less artificial conditions, for this entire time. The various species differ sufficiently in certain parts of their life histories to make it necessary to follow each out separately; and it is not impossible that important differences may be found due to differences in lati-

tude and climate, between northern and southern Illinois; hence each species must be studied in different parts of the state. The most important species—that is the most abundant ones—are not the same in all parts of Illinois, and the relative importance of the various species must be made out for each region separately. The unexplained sudden disappearance, several times noticed by us, of nearly the whole grub population of badly infested fields before their transformation to the pupa, suggests the occurrence among these insects of contagious diseases—a supposition borne out by several field and insectary observations; and the whole subject of their bacterial and other fungus parasites consequently invites attention. The enormous effect of the rapid multiplication, under favorable conditions, of certain insect parasites—a hymenopterous enemy, *Tiphia inornata*, especially—requires a critical and complete study of the life history of these parasitic insects also, especially as there is some probability that we shall be able to increase their efficiency by artificial measures.

No one has heretofore undertaken to work out to a finish this difficult but highly important economic problem, and our present knowledge of the white-grubs is a patchwork of fragments, contributed by a considerable number of observers working on various species and in different parts of the country. The nearest approach thus far made to a continuous investigation of the subject was carried on in this office in the years of 1886–1890, and its results were published in 1891 in Volume III. of "Insect Life."*

They were also incorporated, with some later studies, in the Eighteenth Report of the Illinois State Entomologist, printed in 1894. In the year 1906 I finally began what I now hope may prove to be a steady and comprehensive study of this problem for the state of Illinois; and I have now to report some of the first results of this work, which I have incorporated, however, with other data and conclusions in a way to give us a fairly full synopsis of the present state of our knowledge, and a clear view, consequently, of its deficiencies.

THE ECONOMIC SPECIES.

The kinds of white-grubs common enough in Illinois to attract attention because of their injuries, belong, so far as we now know, to nine species, although it is likely that this list would be longer if the injurious grubs of southern Illinois were as well known to us as those of the central part of the state. Besides these nine injurious

*"On the Life History of the White-grubs." By S. A. Forbes. Insect Life, Vol. III., No. 5, pp. 239–245.

grubs, there are three other very abundant kinds which resemble closely the injurious species, although they are themselves harmless in the grub stage.

Eight of the species known to be injurious belong to the genus *Lachnosterna* and one to the genus *Cyclocephala*. Of the abundant but harmless grubs, one, frequently called the muck-worm because it lives in stable manure, is known to science as *Ligyris relictus*; another, called the carrot-beetle in the adult stage, is *L. gibbosa*; and the third is the larva of the green June-bug of southern Illinois and of the Southern States generally, known in the beetle stage as *Allo-rhina nitida*. All the last three species are injurious as beetles, but only one of them, the larva of the carrot-beetle, is at all injurious as a grub, and then only slightly or occasionally so. The eight species of *Lachnosterna* known to be injurious in Illinois are *L. fusca*, *rugosa*, *inversa*, *implicita*, *gibbosa*, *tristis*, *ilicis*, and *hirticula*; and the injurious *Cyclocephala* is *C. immaculata*.

Life Histories of the Injurious Species.—The life histories of the white-grubs of the genus *Lachnosterna* are very imperfectly known, especially as to the length of time required for the growth and development of a complete generation. The literature of the subject records, in fact, but a single case in which a *Lachnosterna* has been reared from the egg to the adult. An egg of *L. arcuata* laid in Washington about June 8, 1893, hatched in approximately eleven days, and changed to the pupa August 8, 1895, and to the beetle twenty-three days later.* As this beetle would doubtless have hibernated in the earth to emerge the following spring and lay its eggs in June, the entire period from the egg to the egg again was three years. This is the length of the life cycle which has commonly been inferred, from circumstantial evidence, for our species of *Lachnosterna* generally. It is worthy of note, however, that *Melolontha vulgaris*, the European white-grub nearest in classification and habits to our American species, has been found, according to Xavier Raspail, to have, in France, a period of three or four years—the shorter period if the years are moist and the longer one if they are dry.† In Germany, on the other hand, this species has a four-year period at the north and a three-year period at the south, with various occasional exceptions and irregularities of appearance; and a related species, *M. hippocastani*, has a five-year period in north Germany. Our American species of *Lachnosterna* will probably be found to present similar variations of life history.

*"Biologic Notes on the May-beetle *Lachnosterna arcuata* Sm." By F. H. Chittenden. Bull. 19, N. S., Div. Ent., U. S. Dept. Agr., p. 77.

†Bull. de la Soc. Zool. de France, 1891, p. 271; Mém. de la Soc. Zool. de France, 1893, T. VI., p. 202.

Whatever the length of life in the grub stage, all our most abundant species of *Lachnosterna* begin to pupate in June or July in central Illinois, and begin to change to the beetle in August or September, remaining, with rare or doubtful individual exceptions, under ground in this stage until the following March, April, or May. They then emerge from their winter quarters, feed on the leaves of various trees, and pair and lay their eggs in the earth in June and July. An exception should perhaps be made, provisionally, of *L. tristis*, concerning which my records are unusually imperfect, agreeing, so far as they go, with those of the other species of our list, but stopping short before the middle of June. That is, we have an abundance of the beetles collected from the latter part of March through April and May and into early June, most frequently, however, in May, but have no collections in any stage at any date later than June 5. Four of our lots of *tristis*, collected in March and April, were beetles taken from the earth, which must have transformed the preceding summer or fall.

Pupæ of the above species have been taken by us from their underground cells only in June, July, August, and September, and the adult beetles have been found under ground in the cells where they originated, in August, September, October, and November, and again in April and early May. Adults of various species have been seen pairing in May, and in one case in June, and eggs of seven of these species—*tristis* being omitted—have been secured in June and July, much the greater part of them in the former month. So far as my rather scanty records go, the eggs may be expected to hatch from ten days to four weeks from the time of deposit. My dates for the hatching of eggs of known species are, for *inversa*, June 23 and July 11; for *fusca*, June 27; for *implicita*, July 16, 21, and 24, and August 7; and for *hirticula*, July 7.

From this it will appear that white-grubs found in the earth beyond the middle of September will not change to the beetle that year, but, barring destruction by parasites and other fatal accidents, may be expected to pass the winter as grubs and to continue in that stage at least until the following June. This is a point of special economic interest, since the owner of infested fields needs to know whether the grubs in the ground during the latter part of the season will continue there in dangerous numbers during the following spring, or whether he may expect relief from their injuries by reason of their change to the beetle.

The data of my collections, when taken in the aggregate for several years, give little indication of any fixed order of succession

in the first appearance of the different species of *Lachnosterna* in spring. *Inversa*, *fusca*, *rugosa*, *hirticula*, and *tristis* have all been taken by us in the later days of March, and *gibbosa* on April 6. *Implicita* and *ilicis* have made their first appearances about a month later than the average, but, although *implicita* is sometimes excessively abundant, these two species have been much less frequently taken by us than the others, and the record might have been different if the collections made had been equally numerous. The dates of last occurrence are also nearly the same for these species, and their periods of greatest abundance do not vary greatly.

Fusca, however, commonly appears in large numbers at electric lights about a week earlier than the other species, and *gibbosa* is about as much later than the others—a fortnight later than *fusca*. Our records of egg-laying are substantially the same for all the seven species covered by them. So far, consequently, as the mere period of adult activity is concerned, these insects are virtually one species, and we must look to other facts and conditions for any specific distinctions of habit or agricultural relation.

I find that the data of the relative abundance and dates of emergence of the various species derived from electric-light collections disagree widely with the data of collections made from the food plants of the beetles at the same time. Apparently some of the species are more strongly attracted to lights than others. In 1891, and again in 1906, collections were made at Urbana from trees and from lights during the greater part of the active period of the May-beetles, with the results shown in the following table.

LACHNOSTERNA AT LIGHTS AND ON TREES, IN COMPARISON. URBANA.

	1891		1906	
	Lights	Trees	Lights	Trees
No. Specimens	1874	836	142	3484
<i>L. gibbosa</i>	.02	.02	.00	.03
<i>L. inversa</i>	.76	.32	.54	.00
<i>L. dubia</i>	.00	.00	.02	.00
<i>L. fusca</i>	.05	.23	.00	.01
<i>L. rugosa</i>	.00	.00	.24	.06
<i>L. implicita</i>	.00	.00	.15	.72
<i>L. hirticula</i>	.10	.42	.03	.07
<i>L. ilicis</i>	.00	.00	.02	.10
<i>L. tristis</i>	.07	.00	.00	.01

In 1891, when 1,874 specimens were taken from lights and 836 from trees, the dominant species at lights was *inversa* (76 per cent.), *hirticula*, *tristis*, and *fusca* following with ratios of 10 per cent., 7 per cent., and 5 per cent. respectively. The dominant species from trees, on the other hand, were *hirticula* (42 per cent.), *inversa* (32 per cent.), and *fusca* (23 per cent.), the only other species being *gibbosa* (2 per cent.). The results for 1906, when 142 specimens were taken at lights and 3,484 at trees, were equally discordant. The leading species at lights this year was *inversa* (54 per cent.), *rugosa* and *implicita* following with 24 per cent. and 15 per cent. respectively; while the leading species in trees was *implicita* (72 per cent.), followed by *ilicis* and *rugosa*, 10 per cent. and 6 per cent. respectively.

Variation of Numbers in Different Localities and Years.—The numbers of the several species vary greatly from year to year in the same locality, and in different localities during the same season. It consequently happens that the dominant species in a locality may be different in successive years, and that the dominant species in one locality may be different from that in another, within the same year. Collections have not been made on a large enough scale or in sufficiently continuous series to enable us to exhibit these differences in any detail, but the following may serve as illustrations:—

Collections made at a street-lamp in Maywood, near Chicago, by O. S. Westcott,* on seventeen nights from May 9 to June 14, 1887, contained 798 specimens of *fusca* and 313 of *gibbosa*—*fusca* predominating in a ratio of more than 2½ to 1; and collections made the following year at the same place by the same person, on seventeen nights between June 2 and July 2, gave 73 specimens of *fusca* and 1,836 of *gibbosa*—*gibbosa* now predominating in a ratio of 25 to 1. The difference in the collection period of the two years was due to the difference in the weather of the spring, which was backward and stormy in 1888. If we compare the collections of the same periods for these two years—June 9 to 14 in 1887, and June 9 to 13 in 1888—we have 96 specimens of *fusca* to 82 of *gibbosa* in 1887, and 29 of *fusca* to 1,020 of *gibbosa* in 1888.

A similar comparison may be made between the contents of frequent collections from trees made at Urbana through the whole period of activity of the May-beetles in 1891 and again in 1906—836 specimens in the former year and 3,484 in the latter. (See table on p. 139.) In the collections of 1891 the dominant species were *hirticula* (42 per cent.), *inversa* (32 per cent.), and *fusca* (23 per

*Entomologica Americana, Nov., 1888, Vol. IV., p. 155.

cent.), the only other species represented being *gibbosa* (2 per cent.). In 1906, on the other hand, the dominant species was *implicata* (72 per cent.), the remaining species, mentioned in the order of their abundance, being *ilicis* (10 per cent.), *hirticula* (7 per cent.), *rugosa* (6 per cent.), *gibbosa* (3 per cent.), and *fusca* and *tristis* (each 1 per cent.). This latter comparison is vitiated, however, by the fact that the collections were made from different kinds of trees, those of 1891 mainly from butternuts and hickories, and those of 1906 from poplars, willows, elms, and oaks,—another example of the fragmentary and disjointed character of the data now available for a study of this subject.

It so happens that extensive collections of May-beetles were made in 1888 both in Cook county, Ill., by Westcott, and in the District of Columbia by J. B. Smith,* and a comparison of the relative numbers of the dominant species in these two widely separate localities would be possible by their means if it were not for the fact that Westcott's specimens were all taken at lights and Smith's were obtained from trees and shrubs. As already shown, collections are not comparable when made in these different ways.

Much more nearly equivalent collections were made in 1906 by two assistants of my office, one working at Urbana, in Champaign county, between May 26 and June 23, and the other at Elliott, in Ford county, between May 23 and June 5, the first collecting at lights scattered through fields of grass a total of 142 specimens in ten nights, and the second obtaining at a single light in a large corn field 389 specimens in six nights. At Urbana the dominant species was *inversa* (54 per cent.); at Elliott it was *gibbosa* (71 per cent.). At Urbana *gibbosa* was not taken in these light-collections, and at Elliott *inversa* made but 20 per cent. of all obtained.

A further profitable comparison may be made of data contributed by Prof. M. V. Slingerland from the product of light-traps kept in continuous operation at Ithaca, N. Y., during the seasons of 1889 and 1892.† Four hundred and thirty-eight specimens of *Lachnosterna* were taken during the first of these years, and 273 during the second. *Fusca* was much the most abundant species in both years, making 76 per cent. of the product of the traps in 1889, and 90 per cent. in 1892. *Dubia* was next to *fusca* in 1889 (15 per cent.); and this species and *ilicis*, each 4 per cent., were likewise next to *fusca* in 1892. The similarity of the records for these two years is possibly due to a three-year period of the dominant species,

*Proc. U. S. National Museum, 1888, Vol. II., p. 488.

†Canadian Entomologist, March, 1893, Vol. XXV., p. 81.

fusca, but, unfortunately, as no comparable collections were made in the intermediate years, the evidence is not complete. Westcott's Maywood collections, already referred to, on the other hand, hint at a two-year period for *L. gibbosa*. This species predominated over *fusca* in 1886, as shown by records made on five nights, from the 26th of May to the 1st of June, in a ratio of 3.6 to 1, and again in 1888, in a ratio, as already stated, of 25 to 1, but was much less abundant than *fusca* in the intermediate year.

FOOD AND FEEDING HABITS OF THE SPECIES.

The white-grubs and the May-beetles, larvæ and adults of the same insect species, differ totally in their food and feeding habits, the grubs eating the roots of various kinds of plants and the beetles eating the leaves of trees and shrubs. In the absence of any means of distinguishing the species one from another in the grub stage, no evidence has been obtained of any special choice, by any of the species in this stage, among the various elements of the food of grubs in general. So far as known, all of them may take, with equal relish, all kinds of food which any one of them will eat. If the different species of grubs do indeed make definite and varied choice of food, the fact may be ascertained by breeding to the adult, for determination, pupæ and full-grown grubs obtained in various situations near or among different kinds of food plants; but there is at present too little recorded information on this point to permit us to infer any difference whatever in the choices of our more abundant species.

The species of beetles themselves, on the other hand, differ considerably, although not sharply and completely, as a rule, in their choices of food where several kinds are equally accessible to them. Evidence of these preferences has been obtained by us in three different ways: (1) by experimental feedings with beetles kept in confinement; (2) by parallel collections of beetles made from different kinds of food plants; and (3) by the dissection of specimens of various species, made to determine, by an examination of the contents of their alimentary canals, what kind of vegetation they have been feeding on. The first method shows what the beetles may eat under stress of hunger, or perhaps with starvation as a penalty for refusing what is offered them; the second shows what the different species actually choose when a choice is open to them; and the third enables us to determine with certainty what the beetles have eaten where direct observation is impracticable. The results of our feeding experiments have been so different from those ob-

tained by making collections from the food plants at night that they evidently have comparatively little real value. For example, leaves of Osage orange were offered, without other food, to *fusca*, *inversa*, *implicita*, *ilicis*, *rugosa*, and *tristis*. They were eaten moderately by *implicita* and *rugosa*, and slightly by *fusca*, *inversa*, and *ilicis*, but were constantly refused by *tristis*. On the other hand, extensive observations made in the field have given us no instance of actual feeding on this plant in the open air by any of our species, although it is everywhere in common use as a hedge plant.

The following table shows the different kinds of food offered to *Lachnosterna* beetles in breeding-cages in 1904 and 1905, and data as to the readiness with which each sort of leaf was eaten when but one kind of food was placed in the cage.

RESULTS OF FEEDING EXPERIMENTS WITH
MAY-BEETLES (*LACHNOSTERNA*).

	Gibbosa	Inversa	Fusca	Rugosa	Implicita	Hirticula	Illicis	Tristis	Average
Carolina Poplar, (<i>Populus monilifera</i>)..	1	3	3	3	3	3	3	2	2.62
Willow	-	3	3	2	3	-	3	1	2.50
Oak	-	2	3	2	2	-	3	3	2.50
Elm	3	2	3	2	2	3	3	3	2.62
Apple	1	2	3	3	3	3	3	1	2.37
Box-elder.....	1	2	3	1	3	2	2	0	1.75
Plum.....	1	0	3	0	3	3	2	0	1.50
Peach	1	0	1	0	1	1	1	0	.71
White Ash.....	1	2	1	1	3	2	1	0	1.57
Tulip tree, (<i>Liriodendron</i>)..	0	1	1	0	1	1	0	0	.57
Hedge.....	-	1	1	2	2	-	1	0	1.40
Lilac.....	-	1	2	-	1	-	-	-	1.33
Cherry.....	-	1	1	-	1	-	-	-	1.
Corn.....	-	2	2	2	2	-	1	0	1.50
Grass.....	-	2	2	2	1	-	1	0	1.60

1=slightly eaten, 2 =moderately eaten, 3 = freely eaten, 0 = refused to eat, - = not offered.

An attempt was also made to test the general food preferences of each species by offering several different kinds of food in the cage at once. Under these conditions, *L. fusca*, *inversa*, and *implicita* ate most freely of Carolina poplar and willow; *L. ilicis* and *hirticula* ate most freely of oak, but freely, also, of Carolina poplar and elm; and *L. tristis* ate only oak when that was present. *L. rugosa* selected poplar and elm, and *L. gibbosa*, oak and elm.

In 1906, at Urbana, extensive collections were made with equal care from each of the four different kinds of trees which May-beetles

seemed to prefer as food. The beetles were gathered by shaking them from the trees at night and picking up those which fell to the ground.

The following table gives the results of these collections made at Urbana from Carolina poplar (cottonwood), willow, oak, and elm, on twenty-six different nights between May 14 and June 28, 1906.

COMPARATIVE COLLECTIONS OF LACHNOSTERNA FROM FOOD PLANTS. URBANA, 1906.

Species	Poplar		Willow		Oak		Elm	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
<i>L. implicita</i>	1456	.58	855	.34	35	.01	171	.07
<i>L. rugosa</i>	169	.85					31	.15
<i>L. gibbosa</i>	73	.72	7	.07	18	.17	4	.04
<i>L. fusca</i>	39	.85	6	.13	1	.02		
<i>L. hirticula</i>	10	.04	6	.03	209	.86	17	.07
<i>L. inversa</i>	5		4		2			
<i>L. ilicis</i>	2		1		317	.93	21	.07
<i>L. tristis</i>					25	1.00		
Total	1754		879		607		244	
Per cent. on each tree	.50		.25		.18		.07	

From the foregoing table it will be seen that poplar (cottonwood) was the favorite food, 50 per cent. of the specimens being taken from this tree, and that willow follows next with 25 per cent., oak with 18 per cent., and elm with 7 per cent., poplar and willow together yielding 75 per cent. of the insects. Apple leaves were often eaten freely, but no trees were suitably situated for experimental field-collecting, and hence no comparative records were made which included apple. Apple orchards in the southern part of the state have been reported by assistants as sometimes almost stripped of their leaves. This was notably so in Jackson county in 1904. The pecan- and persimmon-trees of southern Illinois often suffer severely by having their foliage eaten by the beetles.

Certain species of the beetles exhibited marked preferences in the choice of food. *L. hirticula*, *ilicis*, and *tristis* had a special liking for oak, the last named being taken from no other tree. *L. implicita*, *gibbosa*, *fusca*, and *rugosa* were most abundant on poplar, *rugosa* seeming to avoid oak and willow. Not enough specimens of *L. inversa* were taken to warrant conclusions concerning its preferences.

All of the May-beetles taken at lights in the open fields at night in 1906 at Elliott, Ford county, and at Urbana, Champaign county, were carefully dissected and the contents of the alimentary canals

were examined microscopically. Nearly 40 per cent. of all the May-beetles taken had eaten nothing. This percentage was much the highest for specimens taken early in the season, 62 per cent., for example, for those caught before June 6. Probably most of these empty beetles had just come from the earth and had not yet begun to feed. Nearly all of those captured in the fields at lights which had taken food had eaten the leaves of trees, as was shown by the presence in their intestines of small pieces of leaves exhibiting the netted vein-structure and other characteristics of the foliage of the common trees of the vicinity. Only six specimens of about six hundred dissected, had eaten the leaves of young corn. Five of these specimens belonged to *L. rugosa* and the sixth to *L. inversa*. Four additional specimens of *L. rugosa* were taken at Urbana directly from corn while feeding on it. As these ten beetles represent only about $1\frac{3}{4}$ per cent. of the whole number examined, the facts indicated by them are of little economic significance except as going to show that May-beetles, of these two species at least, emerging in corn fields at a distance from trees too great to enable them to find their more ordinary food, may nevertheless subsist on leaves of corn. The same facts have been shown with reference to blue-grass, and it seems probable that, in the absence of other food, beetles may be able to live on the blue-grass of our pastures. With their actual powers of flight and their strong disposition to assemble in trees at night, not merely to feed but likewise to copulate, their ability to feed on grass and corn seems to signify but little. Corn, oats, wheat, clover, and grass fields were repeatedly examined in both Ford and Champaign counties with a view to the detection of any injury which might have been caused by these beetles. Occasionally at Urbana, and more frequently at Elliott, corn plants were found which, though uninjured in the evening, were partially eaten by the next morning, and, as already mentioned, four May-beetles (*L. rugosa*) were taken directly from the plants while feeding on them. Dissection of these specimens showed beyond a doubt that they had eaten the leaves of corn. Two hundred and sixty-two specimens of this species were taken in 1906, 169 of them from poplar, 31 from elm, and 62 from other situations, and only 9 of these had eaten corn, as shown by dissection.

MOVEMENTS OF MIGRATION AND DISPERSAL.

As the larvæ known as white-grubs never appear above ground except by accident, and as they are sluggish insects, incapable of rapid locomotion under ground, each is practically confined, so far as

we now know, to the immediate neighborhood of its origin. The grubs change location slowly as their food is exhausted, and injured spots in an infested lawn or grain field will gradually enlarge in all directions, the white-grubs moving outwards into fresh pasturage as the infested vegetation dies from the destruction of its roots. The grubs also sometimes gather in from all directions towards a particularly attractive patch of their food plants; but there is nothing to show that they move from place to place by definite underground migration, or that they cover any considerable distance, such as to take them from one field to another, during the whole period of their active larval life.

The May-beetles also seem local in their distribution. Although very good fliers, they use their wings only to carry them from their place of origin to the trees and shrubs on which they feed and in which they copulate at night, and from these to their daytime hiding places, never moving in swarms, so far as known, or migrating over considerable distances. There is, in short, no evidence of any migration movement of this insect in any stage or under any circumstances, but each locality or considerable neighborhood probably breeds and maintains its own white-grub population year after year. Their most marked movements are the evening flight of the beetles to their food plants, and the morning dispersal from trees to the fields in which the females lay their eggs.

The discovery that certain species, at least, of the May-beetles may feed, and sometimes do feed to a small extent, on corn and grass, and the consequent conclusion that they may not need convenient access to trees for food, raises the important question whether some of these insects, and possibly certain species of them, may not live continuously in the fields, feeding on the crop plants there and laying their eggs in the very places where they themselves originated. If this is the case, collections made in the fields at maximum distances from trees should give us proof of the fact; and I consequently arranged, in the spring of 1906, for the systematic use of lantern traps distributed over an open area of one hundred and sixty acres on the main farm of the University of Illinois, with trees of various sorts in a cemetery along one side of this tract, and no others within less than half a mile from it in any direction. These traps were ordinary kerosene lanterns, with glass globes, placed over large tin trays, each containing kerosene to a depth of about half an inch. These trays were not large enough to secure all the beetles which flew against the lantern globes, but they nevertheless gave satisfactory samples of the beetles flying in the field.

The accompanying plat shows the crops of this tract and the distribution of the lantern traps in each. Forty acres were in corn, seventy acres in grass, thirty acres in clover and alfalfa, and twenty acres in oats. Two of the lanterns were in corn fields, two in clover

Plat showing Distribution of Light-traps.

Cemetery

Road		Road	
New pasture 20 acres 	Oats 20 acres 	Old pasture 40 acres    	
Alfalfa 20 acres 		Clover 10 acres 	Corn 20 acres 
Corn 20 acres 		Meadow grass 10 acres	

and alfalfa, one in oats, and seven in meadows and pastures of grass. None were nearer than a quarter of a mile to trees on whose leaves the May-beetles were feeding at the time, nor farther from them than three quarters. To avoid attracting beetles from these trees, each lantern was provided with a tin shade by which its light was hidden on the side towards the trees nearest to it. These lights were

kept burning all night for fourteen nights between May 20 and June 23 inclusive, and were visited at frequent intervals during each of these nights. The weather was so cold during four nights that the May-beetles were not flying, and no account is taken of these nights in this discussion.

The total product of the twelve traps, thus maintained for ten entire nights, was 142 specimens of May-beetles of the genus *Lachnosterna* and 25 specimens of *Cyclocephala*. No account is taken of the latter because their food habits are very different from those of *Lachnosterna*. The average product of a lantern in one night was only 1.2 of the true May-beetles (*Lachnosterna*), and the largest catch of any one night was 40 specimens on June 18, or $3\frac{1}{3}$ per light. The largest collections were made on three nights between June 9 and 18 inclusive, these averaging 33 per night, or about 3 to each trap. The two collections of May, made on the 26th and 31st of the month, averaged only 6 beetles per night, or 1 to each two traps.

A single light-trap of the same kind, exposed at night without a screen, for ten minutes May 21 and for thirty minutes May 23, close to willow-trees at the border of this field and near the cemetery above mentioned, yielded 11 May-beetles on the first night and 127 on the second—seventy times as many taken in ten minutes by one trap near these trees as were taken at approximately the same date by a trap exposed all night in the open field. There could be no question, consequently, that very nearly all the May-beetles of this neighborhood were concentrated in the trees at this time.

New data have been obtained by our collections and observations of recent years with regard to the nightly movements of the beetles, and these are thus summarized by Mr. J. A. West, who had charge of this work for 1906.

"There is a regular migration of beetles from the fields to the trees in the evening. It takes place in June just about dusk—from a few minutes before to a few minutes after eight p. m. The movement of the beetles is almost simultaneous from the different fields. An observer in one field can scarcely move to another and hope to see the migration. It is usually but a few seconds from the time its beginning is noticed in one place until a companion observer will report its commencement perhaps a quarter of a mile away. Beetles were found rising from the ground in fields of oats, in pasture, old meadow, clover, alfalfa, and in corn. They were most abundant from old pasture and least numerous from alfalfa and corn. They were observed coming from the ground in considerable numbers in oats and clover fields. The following species are mentioned in the order

of their abundance: *L. implicita*, *hirticula*, *ilicis*, and *rugosa*. The evening migration occupies not over fifteen or twenty minutes, and in every instance it seemed completed by 8:20 p. m.

"While the evening migration seemed to result in a complete abandonment of the fields by the beetles, yet the observer may now and then hear a beetle whirr past in the darkness at any hour of the night, and light-traps so placed in the open field as not to attract those from the trees will take specimens in small numbers throughout the night. The beetles distribute themselves regularly over large areas when they leave the feeding grounds in the morning. The following is a record of specimens taken in the fields a quarter of a mile or more from trees, and apparently coming directly from them: *L. implicita*, 11, *L. hirticula*, 5, *L. rugosa*, 31,—total, 47.

All these specimens were taken by hand, the light-traps not seeming to attract them.

"The morning movement is very early. It varies considerably, according to the clearness of the sky. It is so related to the awakening of the birds that it seems as if the first note of the dick-cissel, or other early bird, is the signal for the beetles to fly to their hiding places in the ground. On only two mornings were beetles taken in June after four o'clock. June 18, a dark cloudy morning, a pair of *L. rugosa* were taken at 4:25 a. m. while in copulation on a stem of grass. Ordinarily the movement did not last over fifteen minutes and it very rarely continued for twenty minutes. On the morning of June 7, however, a strong wind was blowing thirteen to fourteen miles an hour from the south. This greatly retarded the flight of the beetles which had been feeding on trees to the north of the fields, and on this morning it began at 3:35 o'clock and continued until 4:10, when the last beetle seen was taken in flight.

"The following notes show the variation in the time of the morning movement of the beetles according to the brightness of the morning and its relation to the awakening of the birds:—

"Morning of June 10, moonlight and very bright. Dick-cissel heard at 3:08; meadow-lark at 3:15; kingbird at 3:20; the following, in order given, from 3:25–3:35,—prairie-chicken, brown thrasher, quail, robin, and horned lark. On this morning the beetle-movement began at 3:18 and lasted until 3:30.

"Morning of June 18, very cloudy and dark. No bird was heard until 3:40, and the movement of the beetles began at 3:45 and was complete in ten minutes. About 3:30 a.m. was the average time for the first bird note, and 3:35–3:45 the regulation time for the morning movement of the beetles."

These data are of special importance as showing the time of night when the beetles are accessible in the trees on which they feed—a subject important to a discussion of measures of prevention and remedy.

HABITS OF REPRODUCTION.

With respect to the reproduction of May-beetles, we need to know at what time of day, in what situations, and especially how soon after emerging, the sexes pair, and when, where, how soon, and in what numbers the females deposit their eggs. Our definite information as to the pairing of the beetles is not abundant, but is sufficient to show that they pair at night on their food plants. The males are much more active than the females,—a fact illustrated by their greater abundance at lights in fields at a distance from trees. In the product of the light-traps used in 1906, as described in this paper under “Movements of Migration and Dispersal” pp. 146-148), the males outnumbered the females about 4 to 1, while in collections made at the same time from trees the number of males was only 39 per cent. of the total number taken. Similar data were given in my Seventh Report.* It will be seen that it does not follow from the greater number of females taken on the food plants that females are actually more numerous than males, but only that the latter are more widely scattered at night, and more generally on the wing.

It has been noticed by some of the office assistants, and particularly by Mr. J. A. West, that May-beetles are sometimes very unequally numerous in neighboring trees of the same kind, one tree containing a buzzing multitude while there are comparatively few on another tree of the same species close by. I have myself once seen a large tree so full of May-beetles in the evening that the noise of their movements was like that of a huge swarm of bees, although the condition of the leaves the following day showed that they had not resorted to this tree for food. Their assemblage in tree-tops is evidently in part for breeding purposes, and not wholly for food.

About fifty pairs of these beetles have been taken by us *in copula*, all but three of them from trees at night. In one case a pair of *L. rugosa* was captured at night by Mr. West from a grass-blade in a pasture, and two pairs of *L. inversa* have been seen copulating in a breeding-cage, also at night. These two pairs had been taken from earthen cells in the ground October 5, 1905, and transferred to the insectary, where they at once went into the earth, first appearing above ground on the 1st of the following May. They began to feed

*Eighteenth Rep. State Ent. Ill., p. 117.

on elm leaves May 17, and paired at midnight May 25. Our observed dates of copulation all fall within the month of May.

The several species of May-beetles may continue active, in a normal season, from one to two months, reckoning this period from the first appearance of the earliest specimens to emerge to the final disappearance of the beetles for the year. In our work of 1906 the dates of first and last appearance of the more abundant species in collections made regularly near Urbana, at night, from willow, oak, elm, and cottonwood (Carolina poplar), were as follows: *L. implicita*, May 13* and June 28 (46 days); *L. ilicis*, May 21 and June 23 (33 days); and *L. hirticula*, May 23 and June 18 (26 days). In New York, on the other hand, Professor Slingerland some years ago obtained *L. fusca* in his light-traps from May 6 to July 5, 1889, and from May 26 to June 28, 1892; *L. dubia* from May 8 to July 5, and from May 30 to June 22; and *L. ilicis* from June 1 to July 30.

CAPTURES OF LACHNOSTERNA AT LIGHT-TRAPS, OPEN
FIELDS, URBANA, 1906.

	<i>Inversa</i>	<i>Implicita</i>	<i>Dubia</i>	<i>Hirticula</i>	<i>Rugosa</i>	<i>Ilicis</i>	Males	Females
May 26.....	4						4	0
May 31.....	6	1	1				5	3
June 2.....	8	3					5	6
June 4.....		6	1	3	4		8	6
June 6.....	2				3		4	1
June 9.....	18	1	1	2	7	2	25	6
June 15.....	22				5		24	3
June 18.....	16	9			15		40	0
June 20.....						1	0	1
June 23.....		1					0	1
Total	76	21	3	5	34	3	115	27

Collections made only from the food plants commonly show a more rapid diminution and earlier disappearance of males than of females. We may take as an example 2517 specimens of *L. implicita* collected from trees on twenty-six different nights between May 14 and June 28, 1906. Thirty-nine per cent. of the specimens taken during the first thirteen days were males and only 15 per cent. of those taken during the last thirteen days. On the other hand, in collections made during the same period by means of lantern traps

*The spring was unusually late this year, and May-beetles did not appear on the wing until May 13.

scattered through the open fields, at a distance from the food plants of the beetles, the ratio of males to females was precisely twice as great during the last half of the period as during the first. Slingerland's data, already referred to, do not support the supposition of a relatively early death of the males. It seems likely, consequently, that females may require repeated fertilization, especially as the eggs are laid gradually, a few at a time.

COLLECTIONS OF LACHINOSTERNA FROM TREES, URBANA, 1906.

	Implicata		Fusca		Gibbosa		Rugosa		Ilicis		Hirticula		Inversa		Tristis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
May 14.....	59	90	3	1												
May 15.....	74	95	8	2												
May 16.....	27	52	5	3												
May 17.....	109	200	1													
May 21.....	24	23							1							
May 22.....	19	25			10				2	1						
May 23.....	193	239	7	7	8	2			3		14	5	2	1		
May 24.....	25	26			2				5	1	2	2				
May 25.....	31	35														
May 26.....	104	135	5	4	4	1			13	9	3	1			1	1
May 30.....	4	25							6	5	1			2		
May 31.....	50	108			17	2			28	24	45	21			6	.5
June 1.....	24	125							4	3	12	6			3	1
June 2.....	45	129							8	8	12	4				
June 4.....	14	96			3				19	14	5	16			3	1
June 5.....	6	54					1		24	24	12	20			1	3
June 6.....	4	36			15	2	3	8	12	3	6	3				
June 7.....	1	9			20	16	4	17	12	5	7	7				
June 9.....	5	41					14	16	15	8	6	4				
June 15.....	4	27					7	13	21	39	8	12				
June 16.....		17					13	17	4	1	1	2				
June 18.....	12	76					13	37	16		2	3	1			
June 21.....		16					7	22	1							
June 22.....		3					3	4	1							
June 25.....							1									
June 28.....		1							1							
Totals																
Males....	834		29		79		66		196		136		3		14	
Females..		1683		17		23		134		145		106		3		11

Our data show about thirty cases of oviposition by seven of our species in our breeding-cages, ranging in date from the 1st of June to the middle of July.* As the beetles have begun to emerge more than two months earlier, it is likely that they spend some time in feeding before oviposition begins. In the Eighteenth Report of this office it is said (p. 118) that the statement commonly made to the effect that the eggs are laid in a ball of earth is clearly erroneous. This assertion must be corrected in the light of numerous experiments made in my insectary in 1906 with May-beetles of several species, all of which so deposited their eggs in the ground that each was found inclosed within an earthen ball, a half inch in diameter, probably formed by the extrusion with the egg of an adhesive fluid which, upon hardening, held together the particles of earth which it had penetrated. This method of inclosure was so general that eggs were most easily found by sifting the dirt in breeding-cages and breaking open the spherical pellets of earth thus separated. The eggs were laid at depths varying from not more than an inch to five or six inches below the surface, the number for each female varying from 44 for a specimen of *L. inversa* to 67 for *L. implicita*.

The following extract from the breeding-cage report of Mr. J. J. Davis will give additional particulars of interest.

L. inversa. June 12, 1906, 1 female beetle in breeding-cage. June 18, the earth examined and 44 eggs found, each in a ball of earth from 3 to 3½ inches below the surface. Eggs of a pure milky color and of an oval shape, measuring 1¼ × 2 mm. By the end of three days they had swollen to a nearly spherical form, now measuring 2 × 2¼ mm. Hatching first observed July 11.

L. hirticula. Beetles collected and placed in breeding-cage June 19, 1906. No eggs were found till July 2, but July 9, 6 were found, each in its ball of earth. The freshest eggs were white with a glossy luster. They measured at first from 1½ × 2 mm. to 2 × 2½ mm. Five days later these eggs had swollen to 2 mm. in diameter, and were 2½ to 2¾ mm. in length.

L. ephelida. A single egg obtained August 4, 1905, from beetles collected at Carbondale, Ill., July 26, and placed in breeding-cage in insectary July 29. This egg was comparatively small and definitely oval, measuring at first 1⅓ × 2 mm., and later 1¾ × 2 mm.

L. ilicis. From beetles collected June 19, 1906, eggs were found in oval balls of earth July 9, none having been present there on the 2d of that month. The eggs were a dull white, quite different from the glossy luster of those of *L. hirticula*. They measured at first

*A specimen of *L. ephelida*, taken July 29, 1905, at Carbondale, in southern Illinois, laid eggs until August 4.

$1\frac{1}{2} \times 2\frac{1}{2}$ to $2\frac{3}{4}$ mm., the shorter diameter later enlarging to 2 mm.

L. crenulata. From a single female beetle placed in a breeding-cage July 15, 1905, three eggs were obtained three days later, deposited at a depth of about an inch. These eggs were oval, measuring $1\frac{1}{2}$ to $2\frac{1}{2}$ mm. They were white when first laid, but changed afterwards to cream color.

L. fusca. Eggs were obtained June 22, 1905, from beetles which had been placed in a breeding-cage April 24. One of these eggs hatched on the 27th of June.

L. implicita. Adults collected at Elliott, Ill., from cells in the earth, were placed in a breeding-cage in the insectary October 13, 1905. They were first seen out of their winter quarters April 28, 1906. June 12, 1906, 3 females were alive and 6 eggs were found by sifting the dirt. On the 20th of June only 1 beetle remained alive, and this was a female. No more eggs were found up to June 25, but on the 5th of July 42 eggs were sifted out of the dirt, each in its separate ball of earth. These were from $5\frac{1}{2}$ to 6 inches below the surface. Those most recently laid, measured $1\frac{1}{4} \times 2$ to $2\frac{1}{4}$ mm., while those which were longest deposited measured $2 \times 2\frac{1}{2}$ mm.

RELATIONS TO WEATHER.

The beetles of *Lachnosterna* transform from the pupa in summer and fall, remaining, as a rule, in their underground cells, from 2 or 3 to 5 or 6 inches below the surface, unaffected, so far as we know, by any degree of cold to which they are likely to be subjected in our climate. Their nocturnal movements after they come out of the earth are, however, easily influenced by the weather. During thirty-one nights, commencing May 14 and ending June 28, 1906, these beetles were studied and collected at Urbana by Mr. West. On five of these nights no beetles were seen or caught, although the fields, the lights, and all the best feeding grounds were visited. The records of minimum temperature for these five barren nights, and the rate and direction of the wind, were as follows:

Date	Minimum Temperature	Rate and Direction of Wind (Anemometer Record)
May 19.....	41° F.	N. E., 6 to 8 miles per hour
May 28.....	42° F.	N. E., 4 to 14 miles per hour
May 29.....	38° F.	S. E., 6 to 12 miles per hour
June 11.....	49° F.	N. E., 12 miles, all night
June 12.....	46° F.	N. E., 14 miles, all night

No beetles were taken on any night when the thermometer registered below 52° , except May 21, when the temperature was 62° at 9 p. m. but fell to 46° before morning. A cold rain or high wind kept them confined at night to their day-time hiding places, and they were never abundant on their food plants, or flying freely, unless the minimum temperature was at least 60° . They appeared in greatest numbers on warm quiet nights following bright sunny days. The beetles continue feeding during rain if a storm comes up during a night favorable to their movements; and even their flights are not wholly suppressed by moderate rain if the weather is warm.

MODES AND PLACES OF HIBERNATION.

Our common white-grubs hibernate, in the latitude of central Illinois, in the two stages of larva and beetle, and in these stages only. In fifty-seven collections, distributed over several years, obtained by following the plow in fall and in spring, not a single pupa of these species has occurred, although recently transformed beetles, still inclosed in their pupal cells, have been collected by the hundred. The pupa of *Lachnosterna* may possibly go through the winter now and then, transforming the following spring, but this is certainly an extraordinary occurrence in our latitude, quite insignificant as a factor in the life history of the species. It is also a very unusual thing for the beetles to come out of the ground in fall. Indeed, those taken from the earth and placed in breeding-cages in either fall or early spring, commonly bury themselves without delay. Now and then a single specimen may be found active in fall, but we have seen but one such case in the course of our several years' work. The beetles are evidently more resistant to cold than the grubs, and do not attempt, as a rule, to escape by going farther into the ground with the approach of winter.

During the summer most of the grubs are near the surface of the soil. A small percentage may be found to a depth of eight or even ten inches, but the average is about three inches. In late fall they begin to go down as a protection against the approaching winter's cold, and may reach a depth of two to two and a half feet. In October and November, 1905, the downward movement of the grubs infesting a field of corn, part of which had been completely destroyed by them, was followed by digging over, on each of five days, several areas each three and a half feet square, and counting the grubs exposed. The following table gives the dates at which this search was made, the average number of grubs found for each square of three and a half feet, the range in depth of the grubs dug out, and the average depth for each date.

Date	Average Grubs per Square	Range in Depth	Average Depth
Oct. 3, 1905....	29.2	Near surface to 8 in.	3.5
Oct. 10, 1905....	22.6	Near surface to 10 in.	3.1
Oct. 23, 1905....	25.3	Near surface to 10 in.	3.1
Oct. 31, 1905....	22.	Near surface to 16 in.	6.4
Nov. 22, 1905....	24.75	Three in. to 23 in.	10.

November 22, the last of the above dates, most of these grubs were from 7 to 14 inches below the surface; but one was found only 3 inches down, seven had stopped at a depth of about 6 inches, and three had gone to 20 to 23 inches below the surface. The ground did not freeze permanently until several days after this date.

The grubs approach the surface in spring when the frost leaves the ground and the soil becomes fit to plow, and one often sees in the bottom of the furrow the tubular burrows made by them in coming up from their winter quarters.

PRINCIPAL ENEMIES.

Swine.—Pigs are by far the most destructive enemies of white-grubs and of May-beetles. They are extremely fond of these insects, and of all others within their reach which are large enough to attract their attention, and the diligence with which they will tear in pieces the sod of an infested pasture, and the depth to which they will dig in pursuit of grubs in cultivated ground are matters of common observation. They will also search out and destroy the May-beetles in May and June if allowed to range over pastures and meadows where these insects hide by day and to which they resort to lay their eggs. Pigs are consequently our most useful agents for the destruction of these insects—a point which will be more fully discussed in this paper under “Measures of Prevention and Remedy.”

Crows and Blackbirds.—Next to pigs the most efficient destroyers of white-grubs among our common larger animals are crows and crow-blackbirds, both of which eat them greedily where they can find them in sufficient numbers to make them an important article of food. Evidence on this point is less positive with respect to crows than concerning blackbirds. Mr. W. B. Burrows, of the U. S. Department of Agriculture, who has studied the food of the common American crow by examining the contents of more than a thousand stomachs, reports that he has found white-grubs in a comparatively small number of these stomachs, but that May-beetles had been eaten by very nearly all the crows taken at a time when these

insects were abundant in the beetle stage, making, indeed, the greater part of the insect food of all the crows collected at that time.

To these well-known facts I have to add two significant items of observation reported to me by my field assistants. One of these, Mr. E. O. G. Kelly, who was engaged during much of the season of 1906 in a field study of injuries by white-grubs, unusually serious that year in central Illinois, tells me that he often saw considerable numbers of crows following after the plow in fall, evidently picking up white-grubs, and that he has also seen flocks of crows alight in a badly infested pasture and tear the sod in pieces in search of the grubs, fighting with each other for their possession when thus exposed. Another assistant, Mr. A. O. Gross, employed last fall in collecting data for a census of the bird life of Illinois, found, in a trip across the state made on foot in September and October, that next to the horned lark, crows were the most abundant birds on plowed ground, averaging seventy-nine per square mile in all the recently plowed fields crossed on that trip. They could have had no other object there than the search for insect food.*

In a study of the food of blackbirds, made by Mr. F. E. L. Beal for the U. S. Department of Agriculture in 1894, it was found that these birds ate either beetles or grubs in every month from March to October inclusive. In May these insects made more than a sixth, and in June one ninth, of the entire food. Many stomachs were found to be literally crammed with grubs; and in many more, grubs had formed a large part of the previous meal.

The Common Grub Wasp (Tiphia).—Much the most important insect enemy of the white-grubs is a wasplike insect belonging to the hymenopterous genus *Tiphia*. It is a slender, jet-black species, usually about two thirds of an inch long, but sometimes smaller, and with wings either clear or more or less deeply tinged with dusky yellow. It enters the ground in search of the grubs, follows them up in their burrows, and lays on the back of each grub a single egg, which hatches in a little over a week into a footless, maggot-like larva. This larva adheres to the surface of the insect, punctures its skin and sucks its blood for a time, but finally eats it up. The *Tiphia* larva then spins, under ground, an oval brown cocoon within which it goes through its transformations, coming out as a winged insect the following summer. The rate of multiplication of the species is not known, but it is certainly sufficient to enable the *Tiphia* virtually to destroy, under favorable circumstances, the entire grub population of a badly infested field.

*"An Ornithological Cross-section of Illinois in Autumn." By S. A. Forbes. Bull. Ill. State Lab. Nat. Hist., Vol. VII., Art. IX., p. 318.

The method of the operations of this insect and the main facts of its life history have been worked out in my insectary during the past two years by Mr. J. J. Davis and Mr. J. A. West from cocoons and infested grubs sent in by Mr. Kelly from fields at Elliott, Ill. Thirty-three *Tiphia* cocoons were used in these observations, twenty-one of which were obtained November 25, 1905, and twelve April 27, 1906. From those collected in fall the winged insect emerged at thirteen dates between June 19 and July 28, 1906, and those obtained in spring yielded the adult on eleven dates between June 26 and August 22. These collections consequently do not represent different broods. Only seven of the adults obtained were males, and twenty-five were females, the sex of one being undetermined.

A pair were seen *in copula* in one of the breeding-cages at 9:30 p. m. July 1, and eggs were laid on grubs in the insectary from June 29 to August 21. One lot of young white-grubs brought in September 20, 1906, were already badly infested by very small *Tiphia* larvæ about one eighth of an inch in length. As insectary observations show that the eggs hatch in from seven to ten days, and that the young larva reaches the length of an eighth of an inch in about a week, it appears that the eggs for these larvæ were laid a little later than September 1. The period of oviposition of this grub wasp is thus something more than two months.

In several cases a female *Tiphia* was induced to go through the whole operation of preparing her victim and depositing her egg upon it above ground in a breeding-cage, where she could be continuously watched, and the facts thus learned are unusually interesting. Like others of its family—the digger-wasps, or *Scoliidae*—these insects sting their prey before attaching the egg to it, with the effect to paralyze it more or less completely. Mounting the body of the grub, which struggles violently against the attack, the *Tiphia* seizes with her mandibles the skin of the back just behind the head, curving her body downward around the side of the grub, with the tip of her abdomen beneath and just behind the head, and then, after feeling about with the abdomen for a time, finally stings her victim, with the effect suddenly to quiet its struggles and reduce it to helplessness. Then the *Tiphia* reverses her position and works the tip of her abdomen backward and forward for several minutes in one of the grooves or creases on the back of the larva, usually not far behind the head, apparently smearing the surface there with a viscid fluid, after which she deposits her egg on this sticky surface and goes away.*

*The above account is based on insectary observations and experiments. Several white-grubs parasitized by *Tiphia* larvæ have been found in the field since this was written, and in every case the larva was on the under side of the body between the thoracic legs.

The larva, at first almost completely paralyzed by the puncture of the sting and the venom doubtless injected at the same time, slowly revives, recovering presently its full powers of locomotion, so that it is indistinguishable by its behavior from its fellows which have not been stung. The stinging, in this case, is thus a means of quieting the struggles of the grub in a way to permit the *Tiphia* to attach her egg to its back. Commonly, of course, these operations go on under ground. A *Tiphia* introduced into a breeding-cage containing grubs in the earth disappears under ground herself, and does not come out until she has found and infested a grub.

Repeatedly, where grubs were exposed to attack on the surface of the dirt in breeding-cages, the *Tiphia* merely stung them at first, and then proceeded to bury them before depositing her egg. For this purpose, she undermined the grub by digging the earth from beneath it, pulling its body about by means of her jaws until it was in proper position to enter the hole, gradually digging deeper, and finally burying it completely. In one case in which the operation was timed, the grub was buried in ten minutes after it was stung. Sometimes the *Tiphia* abandoned an attempt at burial, and left the grub without placing an egg on it after it was stung.

Apart from that general exhibition of a wonderful adaptation of its actions to the needs of its prospective progeny which this *Tiphia* shares with many other wasps, and especially with those of its own family, there are two points of peculiar interest in this account. It is an unmistakable fact that the effect of the poisoning of the grubs by the *Tiphia* is merely to paralyze the victim temporarily; to overcome its resistance and reduce it to helplessness while the *Tiphia* egg is being placed in position. The sting is used as a mere aid in the struggle of the *Tiphia* with a stronger insect. This fact may point to the explanation of the origin of the remarkable instinct of the solitary wasps to sting and paralyze their prey.

More remarkable still, however, in the light of our present knowledge of the habits of *Tiphia*, is its frequent burial of white-grubs exposed to it on the surface of the ground. Since digger-wasps in general are parasites of underground larvæ only, since the *Tiphia* is not known to infest any insects except white-grubs of the genus *Laclnosterna*, and since in nature it can never find these grubs above ground, its deliberate burial of exposed grubs has all the appearance of a line of action extemporized to meet a previously unknown condition. Either the *Tiphia*, disturbed at finding its prey exposed, buries this as a result of impulse aided by intelligent contrivance, or we shall find, when its habits are known in full, that it

does sometimes normally infest and attack insects exposed above ground by their habits, burying them as a matter of instinct after it has placed its egg. *Tiphia* has not, in fact, been studied as an independent species, but all the data concerning its habits and life history have been gathered in the course of studies of the white-grubs.

The egg of *Tiphia* remains firmly glued to the back of the chosen grub, and hatches in seven to ten days. The young larva breaks its way out from the egg at one end, and, although it begins at once to feed, it does not at first free itself from the shell, but as it grows this finally splits and breaks away. When it first emerges the larva measures slightly more than a millimeter in length. From our scanty data it appears that it takes about two weeks to get its full growth, and that it doubles its size in the last two days of its larval life, during which it is engaged in devouring the body of its host. Previous to this time it has been adherent to the skin of the grub whose fluids it has lived upon. When full grown it is from two thirds to four fifths of an inch in length.

The cocoons are cylindrical ovate, from 17-22 mm. long, clay-colored at first, and wood-brown or cinnamon-brown when older. From our observations thus far made it appears that the larva hibernates within the cocoon, not pupating until the following spring. The adult emerges from a little one side of the larger end, in which it leaves a ragged and irregular opening. In several cases the abundance of these conspicuous brown cocoons in the earth was such as to indicate an enormous destruction of white-grubs, and there is no doubt that this parasite is an important agent in checking destructive uprisings of these insects.

That this wasp, parasitic on white-grubs, is itself parasitized, is shown by the results of observations made on *Tiphia* cocoons collected April 27, 1906, and kept in breeding-cages during the summer. From these emerged, July 7, 16, and 31, adult bee-flies (*Bombyliidae*) of the species *Exoprosopa fascipennis*, each freeing itself from the *Tiphia* cocoon by cutting out a circular piece at the larger end. The eggs from which these flies resulted were probably laid on the *Tiphia* grub in 1905, before the cocoon was spun.

MISCELLANEOUS INSECT ENEMIES.

Macrophthalma disjuncta.—This little tachinid fly was mentioned in my Seventh Report as bred repeatedly from dead white-grubs, but I was nevertheless uncertain that it was a parasite. Lately its parasitic nature has been proven by repeatedly breeding it from

living grubs kept in breeding-cages in my insectary. Adults have emerged in these experiments March 26, June 8, July 12, and August 8, and others have been taken at electric lights July 9, and in a corn field September 27. Those appearing March 26 lived in confinement until May 14. We have thus seen these insects alive in every month from March to September inclusive. In the breeding-cages, remains of a white-grub were commonly found associated with the cocoon of the parasite.

The adult of this species is a large blackish-gray fly with a general resemblance to the common large blow-fly, but with a grayish white sheen on the basal half of each segment of the abdomen, giving the effect of equal alternating cross-bands of black and gray.

Ophion bifoveolatum Brullé.—This well-known parasite of the white-grub has been reared by us several times from these insects. In one case the head and skin of a grub were woven into the wall of the cocoon of the parasite. The species has been bred by us repeatedly from cocoons collected from the latter part of July to the first of September, and kept in breeding-cages through the winter, adults appearing from March 31 to April 27.

The adult is a large, slender-bodied, dark red ichneumon-fly; and the cocoon is quite regularly elliptical, a half inch long by a fourth of an inch thick at the middle, smooth, dull brownish, or more or less blackish—especially towards the end.

Sparnopolius fulvus Wied.—This bee-fly, which we have sometimes noticed in corn fields and have collected from miscellaneous sweepings of vegetation in midsummer, also proves to be a parasite of the white-grub, as shown by breeding-cage work done in 1904—1906. It was first detected in this relation by Mr. E. P. Taylor, of my office, who found a white-grub at Elliott, Ill., August 25, 1904, with a dipterous larva attached to its back. This was placed in an insectary cage, which was not examined until April 21, at which time the white-grub had been completely destroyed, and the larva had completed its transformations. It probably had emerged in the fall of 1904. A larva of this same species was next collected July 24, 1906, from among corn roots at Effingham, Ill., and was placed in a breeding-cage to obtain the adult. It pupated August 22, and emerged as a winged insect September 10. All our open-air collections of this fly have been obtained in August.

The adult is about as large as a common house-fly, but is covered with erect yellow fur. The pupa is not inclosed in the last larval skin. Its head bears three large points on each side anteriorly, and a smaller pair beneath at the base of the mouth-parts. The last seg-

ment of the pupa is rather narrowly truncate, with a small slender spine on each side of the truncation, and a shorter one beneath each of these.

Considerable numbers of another species of parasitic larva were taken by Mr. Kelly at Elliott, Ill., August 29 and September 20, 1906. These were evidently white-grub parasites, as the remains of the grubs were still clinging to several of them. This species is still in the larval stage at this writing.

Three yellow coarctate meloid larvæ were also found by the same assistant in an infested oats field with the remnants of white-grubs attached to them, and another was taken in a similar condition October 10. These specimens have not yet matured.

Pyrgota undata Wied.—One of the most interesting parasitic enemies of the white-grubs is a large, rather unusual-looking fly of the family *Ortaliidæ*, noticed by Mr. J. A. West, an assistant of my office, as abundant among the beetles at night. Now and then May-beetles were seen to drop to the earth, trying to rid themselves of the adult flies which were clinging to their backs, each with the last segment of the abdomen thrust in between the wings and wing-covers of the beetle and firmly held in place over the middle of the abdomen. The flies were apparently thus thrusting their eggs into the backs of the beetles through the thin dorsal skin beneath the wing-covers. The tip of the abdomen of the female fly is admirably adapted to this object, being hard and subconical, and directed downwards at a right angle to the axis of the body.

The relations of these insects were experimentally determined by confining, June 9, 1906, adult May-beetles in a breeding-cage with several of the flies. These would light on the backs of the feeding beetles, which would at once drop to the ground with the flies clinging to them. Whenever a beetle spread its wings for flight the insect on its back inserted the tip of its abdomen between the May-beetle's wings, evidently depositing an egg in its back. Beetles so treated lived for some days, and then began to die. On the 27th of June, five of the beetles were dead, and in the bodies of two of these, dipterous maggots were found. July 10, three of the beetles contained each a dipterous puparium, which remained unchanged until May of this year, when all produced adults of *P. undata*. August 29 and September 20, 1906, several puparia were found in the bodies of dead May-beetles, and these, kept in breeding-cages through the winter, produced adults of *P. undata* May 14 and 17, 1907. Like experiments begun during the present year have progressed similarly to the time of writing. Adult flies of this species

were again frequently seen June 12 to 18, 1907, among May-beetles on trees at night, no less than twenty-six specimens being captured. These flies have also been occasionally taken at electric lights, and in various situations by day during different years, from May 20 to June 17.

The puparia of these parasites are dull black, broad ovate, widest at the posterior third. At the tip is a small shallow excavation encircled by a rugose ridge, which is elevated latero-dorsally into a pair of short irregular tubercles, the tips of which are about a millimeter apart. Length 7-8 mm.; greatest diameter, 4.5-4.8 mm.; diameter of anterior end, about 3 mm. The adult flies are yellow-brown, three eighths to half an inch long. The head is subtriangular, the thorax globose, the abdomen slender at base, enlarging apically. The wings are three eighths to half an inch long, conspicuously and characteristically marked. The entire anterior margin of the wings has a broad brown border reaching half way across the wing, and having two broad saw-tooth-like extensions attaining the posterior margin, one at the middle of the apical half and the other at that of the basal half. The first two abdominal segments are about as long as broad, and connate; the next four, in the female, are very short, followed by the genital segment, which is very large, shining, directed downwards and curved slightly forwards.

The male abdomen is similarly shaped: the two basal segments are followed by two more about twice as long as the corresponding ones in the female; the next segment is a little longer than broad, vertically directed, bearing the genital segment, which is directed somewhat anteriorly. The eyes are larger in the female than in the male.

Other Dipterous Parasites.—In 1905 a May-beetle of the species *Lachnosterna crenulata* found near Urbana July 15, laid three eggs, and died about the 29th of July. On August 5 an adult tachinid emerged from the body which Mr. Tyler Townsend, of the U. S. National Museum, regards as a new species—*Viviana*. Two dipterous larvæ were found June 27, 1906, in a May-beetle taken alive May 31. July 10 these larvæ had formed puparia, and adult tachinid flies emerged May 17 and 18 of the following year. These are slightly larger than a house-fly, with black subquadrate thorax, the anterior angles each with a triangular red spot. The puparium is very dark red, almost black, subcylindrical, with rounded ends. Length, 7 mm.; width, 3 mm. It is smoothly rounded behind, with a pair of low tubercles placed close together. The species has not been determined.

RELATION TO SOIL AND SUBSOIL.

It is a matter of common opinion that injuries by white-grubs are more serious on the higher, lighter, and drier parts of our cultivated areas than on the lower and moister parts, but no exact observations have been made to show whether this apparent difference is real under all conditions, and whether, if so, it is due to a greater abundance of the grubs on high lands than on low, or to a lesser average power of recuperation and resistance on the part of plants growing in comparatively light and less fertile soils.

I began in 1904 and 1905 to accumulate data on this and allied points, by having collections of white-grubs made by persons following the plow, who recorded for each field and situation the number of grubs found in each quarter of a mile of furrow. A record was also made, for each field examined, of the succession of crops it had borne for the five years preceding, of the character of the soil, the lay of the land, the conditions as to drainage and to fertilization, and the relation of the field to trees and shrubs on which the parent beetles of the grubs might have found food. Collections were made on this plan from seventy-nine fields in the following twelve counties of central and southern Illinois: Stark, Peoria, Woodford, McLean, Champaign, Macon, Macoupin, St. Clair, Washington, Marion, Jackson, and Union. This work was interrupted by lack of funds and by diversion of assistants to more pressing problems before any sufficient mass of data had been obtained to enable me to draw satisfactory general conclusions on any one of the points of principal interest. So far as they go, they show that the grubs were more abundant on the higher and drier parts of the country than on the lower and moister parts, and that the fewest eggs were laid by the parent beetles in corn fields and the most in grass-lands. Thirty-eight low-land fields gave an average of 21 grubs exposed in a mile of plowed furrow, and 41 of the high-land fields an average of 31 to the mile. The three largest numbers found in any fields were 208, 164, and 140 grubs to the mile, all on high ground. The largest numbers in any of the low-land fields were 112 and 104 in two of them. Again, the average of fields which had been in corn continuously for at least three years preceding was 17 grubs exposed in each mile of furrow, and that of fields which, although in corn at the time, had been in grass for several years preceding, was 37 grubs to the mile. It is evident that useful information may be obtained from data of this description if they are accumulated in sufficient number and are properly classified.

RELATIONS TO AGRICULTURAL MANAGEMENT.

Injuries by white-grubs are influenced to a considerable extent by the system of farming, and especially by the succession of crops; by the management of pasture-lands, in which, if left wholly to themselves, they are likely to accumulate in increasing numbers year by year; and possibly, also, by the time of the year when infested lands are plowed. While the old idea that white-grubs are essentially insects of pastures and meadows has been exploded by observations of recent years, it still remains true that, other things being equal, they are most abundant in grass-lands, and consequently most injurious to other crops if these follow within one or two years upon an infested pasture or meadow. They seem particularly liable to accumulate in an old turf which has lain unbroken for several years, and are less likely to be destructive where there is a quick rotation of crops, including a short period in grass, to be followed by one or two years in clover. The modern stockman's practice of herding cattle and pigs together is an excellent one from our standpoint, since the pigs, in following the cattle, are likely also to search out the grubs in the turf and to keep the sod practically free from them.

It is a matter of common, though not universal, opinion among farmers who have watched the work of the white-grubs that fall plowing of infested lands is preferable to spring plowing. In the absence of any apparent reason why this should be so, and in the absence also of any experiments upon the subject and of any considerable number of exact observations, this supposition must be regarded as doubtful. Our own field reports give thus far but a single instance, reported by Mr. Kelly in 1905, of a notable difference in white-grub injury corresponding to a difference in the time of plowing of different parts of the same field; and this instance is by no means clear, since there was injury by grubs in both parts of this field—much greater and more extensive, however, on the spring plowing. The white-grubs were also reported as less abundant in the part of the field plowed in fall, averaging there one grub to the hill of corn as compared with seven to the hill found in the part plowed in spring. The data of this observation are incomplete, however, and this difference in number of grubs may have been due to something else than difference in the time of plowing.

INJURIES TO CROPS.

Injuries to crops by white-grubs and May-beetles are often of the most serious and extensive character. The beetles by their destruc-

tion of leaves of trees and shrubs in spring not infrequently cause the death of those preferred by them for food, and the grubs are particularly destructive in towns to the turf of lawns, in nurseries to young evergreens, in the fruit plantations to strawberry vines, and on the general farm to grass and corn.

The injury by grubs is due, in all cases, to the destruction of the roots of the plants infested and the consequent weakening or actual killing of the plant. The nature and extent of the injury to corn is well illustrated by observations made by one of my assistants, Mr. Kelly, in a field near Ludlow, in Champaign county, about ten acres of which were almost completely destroyed. By digging up to a depth of twenty inches, and searching all the soil belonging to each of sixty hills of corn—an area, that is, three and a half feet square for each hill—it was found that this badly injured area contained an average of 3,460 grubs to the hundred hills, or more than 34 to the hill,—a total of about three hundred pounds of grubs to the acre of corn. The plants varied in height from two inches to six feet, and the total number of ears borne by two thousand hills was 786, all small ears or nubbins.

PREVENTION AND REMEDY.

The subject of preventive and remedial measures was somewhat fully treated in my Seventh Report (pp. 127–137), and there is nothing important to add to that discussion at the present time beyond a statement of the results of an experiment with pigs as a means of clearing the grubs out of an infested field. This experiment was made in the field above referred to, near Ludlow, Ill., ten acres of the worst injured part being surrounded with a temporary fence, and one hundred pigs averaging seventy-five pounds each, together with eight large sows, being turned into the inclosure September 23.

By October 13 the pigs had rooted over the whole surface of the ten-acre lot, going, in some places, to a depth of ten or twelve inches. An area equivalent to twenty corn hills was now examined to a depth of twenty inches, with the result that an average of 4.8 grubs per hill were found, as compared with 34.6 per hill at the beginning of the experiment—a benefit of 86 per cent. in twenty days. The grubs found in the field at this time were usually eight inches or more below the surface.

The pigs were in this inclosure until October 20, when they were removed to another badly injured part of the field, and a final examination of the plot was made. In an area equal to ten hills of

corn only two grubs were found—a benefit of over 99 per cent. destroyed by the pigs in twenty-seven days. As the grubs were at this season going down to escape frost, the hogs were burrowing in pursuit of them, sometimes to a depth of two feet.

Although these pigs remained perfectly thrifty, it is proper to say that there is one possibly serious objection to this very common use of swine as a means of keeping in check the white-grubs in grasslands and of clearing them out of fields of corn. It has been shown by Dr. C. W. Stiles, of the U. S. Bureau of Animal Industry,* that one of the most injurious intestinal parasites of swine, known as the giant thorn-headed worm (*Echinorhynchus gigas*), passes one stage of its life in certain of the white-grubs, and that pigs become infested by it by devouring infested grubs, which themselves obtain it by way of the excrement of the pigs. Where either grubs or pigs become infested by these parasites the situation is more or less dangerous if pigs are allowed to eat the grubs; but pigs which have never been pastured are certain to be free from these parasites, and grubs growing in fields which have not been pastured by pigs are likewise certain to be free from them. The use of such pigs upon such fields would consequently be without danger from this source, and a little attention to these facts will avoid any injurious consequences. That is, if pigs not previously allowed to run out are turned into fields on which pigs have not been pastured within three years, there will be no danger that they will become infested by these thorn-headed worms.

The general measures discussed in my Seventh Report are essentially a destruction of the May-beetles before they have laid their eggs, and the distribution among the grubs of the germs of their contagious diseases. Nothing has thus far been done to test the possibility of the collection and distribution of parasites other than those of contagious diseases, and the latter subject can not by any means be said to have been worked out to final conclusions.

The May-beetles may be destroyed either by spraying repeatedly with arsenical poisons the trees on whose foliage they feed; by shaking or jarring them down in the cooler parts of the night from the trees and shrubs on which they are feeding, and collecting them for destruction; and by trapping and killing them at night by means of lanterns fastened over tubs or traps containing water covered with a film of kerosene. The grubs may possibly be kept in check by the distribution among them of the germs of their contagious diseases obtained by artificial cultivation,—a method which has been

*“On an American Intermediate Host of *Echinorhynchus gigas*.” By C. W. Stiles. Zool. Anz., Feb., 1892, p. 52.

used with some success against the white-grubs of France. The main dependence in the Old World, however, has been a thoroughly organized movement for the collection of the beetles from the trees at night, the usual method of securing general action being to pay a sufficient price for the beetles in quantity to make their collection a profitable enterprise during the time of their presence on the trees. This method can be used to advantage only by owners of very large estates or by communities or combinations of farmers acting together for their common benefit. The same may be said of the destruction of the beetles by poisoning their food. If the ordinary land owner were to proceed by himself, it is probable that his fields would become infested by invasion from without even though he might destroy every May-beetle on his own premises. The least promising of these methods is the simplest and the cheapest of them all—that of collecting the beetles by lantern traps. These take effect much the most strongly upon the males, and collect, under the most favorable circumstances, only a comparatively small percentage of the beetles in their neighborhood. Furthermore, it is available only on dark and relatively quiet nights.

What may be done by way of general concerted action is well illustrated by a campaign of destruction carried on against the white-grubs of the Swedish province of Halland during the ten years from 1885 to 1895, within which time 29,736 bushels of May-beetles and their larvæ were collected at an expense of \$15,554, or about 52 cents a bushel, the state usually paying half of this sum, the Economic Society of the province a fourth, and the communes or counties the remaining fourth. The effect was especially shown in the gradual reduction in the number of the beetles collected—from 14,801 bushels in 1887 to 5,611 in 1895, although the number of communes participating in the work had increased in the meantime, and the area covered by the collections was correspondingly greater.*

So far as is now to be foreseen, organized work of some such description will finally be necessary to the control of the white-grub pest in Illinois, and throughout America generally.

*August Lyttkins, in *Entomologisk Tidskrift* for 1897. Stockholm, 1898.



PLATE IX

A COMMON WHITE-GRUB, *Lachnosterna rugosa*. Fig. 1 - pupa, length about $\frac{7}{8}$ inch. Fig. 2 - egg, diameter about $\frac{1}{10}$ inch. Fig. 3 - adult, length about $\frac{3}{4}$ inch. Fig. 4—larva, about twice natural size.



1



2



3

PLATE X

THE COMMON GRUB-WASP, *Tiphia vulgaris*. Fig. 1 — larva, about three times natural size. Fig. 2 — cocoon, length about $\frac{5}{8}$ inch. Fig. 3 — adult female, length about $\frac{1}{2}$ inch.



PLATE XI

Fig. 1—WHITE-GRUB PARASITE, *Spartanophilus fulvus*, adult; length about $\frac{1}{3}$ inch. Fig. 2—A MAY-BEETLE PARASITE, *Pyrgota undata*, adult; length about $\frac{1}{2}$ inch.

ERRATA.

Page 115, in description of Fig. 7 read $\frac{1}{2}$ for $\frac{1}{3}$, and in that of Fig. 8 read *slightly more than before natural size*.

Page 124, line 13 from bottom, for R. M. Webster read R. L. Webster.

Page 136, line 14, dele *inornata*.

Page 137, line 8, for *gibbosa* read *gibbosus*.

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TWENTY-FIFTH REPORT

OF THE

STATE ENTOMOLOGIST

ON THE

Noxious and Beneficial Insects

OF THE

STATE OF ILLINOIS

FOURTEENTH REPORT OF STEPHEN A. FORBES

1909

Smithsonian Institution

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INTRODUCTION

With the passage, by the Forty-fifth and Forty-sixth General Assemblies, of laws enlarging the scope of the work of the State Entomologist's office and greatly increasing its resources, it has become desirable and possible for assistants of the office to prepare, for its regular reports, articles on special subjects assigned to them, or upon which they have personally done an important amount of investigation or experimental work. The present report is the first to be prepared under the new conditions, and the principal article in it is by Dr. J. W. Folsom, who has served during his vacations as a university instructor in entomology as a temporary assistant to the State Entomologist.

Consistently with the present method of publication of papers prepared by the Entomologist and his assistants, the three articles of this report have been previously issued as Bulletins 130, 131, and 134 of the Agricultural Experiment Station of the University of Illinois; Bulletins 130 and 131 in December, 1908, and 134 in April, 1909.

The following are the state laws recently passed respecting the work of the Illinois Entomologist:

AN ACT to provide for the office of the State Entomologist, to define its duties, and to extend its equipment.

SECTION 1. *Be it enacted by the People of the State of Illinois, represented in the General Assembly:* That it shall be the duty of the State Entomologist to investigate, by himself or by his assistants, all insects dangerous or injurious in this State to agricultural and horticultural plants and crops, to live stock, to nursery trees and plants, to the products of the truck farm and the vegetable garden, to the shade trees and other ornamental vegetation of cities and towns, to the products of mills and the contents of warehouses, and to all other valuable property, and to investigate all insects in this State injurious or dangerous to the public health; and he shall conduct experiments with methods for the prevention, arrest, abatement and control of injuries to person and property by such insects, giving no preference in his investigations to one part of the State over another. He shall, further, instruct the people of the State, by lecture and demonstration, as may in his judgment be practicable and necessary, in the best methods of preserving and protecting their property and their health against injuries by insects; and he shall prepare, from time to time, articles on the injurious and beneficial insects of Illinois, containing the results of his researches, which articles shall be published as bulletins of the Agricultural Experiment Station, and shall also be issued biennially in an edition of one thousand copies as his official report. He shall present to the Governor biennially an executive report describing the operations and publications of his office, together with a financial statement in detail.

§ 2. To carry out the provisions of this Act there is hereby appropriated the sum of twenty-five thousand dollars (\$25,000.00) [] per annum: *Provided*, that five thousand dollars (\$5,000.00) per annum, or so much thereof as may be necessary, shall be set aside for expenses incurred by the State Entomologist under the "Act to prevent the introduction and spread in Illinois of the San Jose scale and other dangerous insects and contagious diseases of fruits:" *And, provided, further*, that the work outlined in this section shall be carried out on lines agreed upon by the State Entomologist and an advisory committee to consist of the director of the Agricultural Experiment Station, two members to be appointed by the Illinois Farmers' Institute and two members to be appointed by the Illinois State Horticultural Society.

§ 3. The advisory committee herein named shall meet at such times and places as may be designated by the State Entomologist, or upon a request of a majority of the committee. They shall serve without compensation, except for expenses, to be paid out of the appropriation herein made.

* * * * *

AN ACT to prevent the introduction and spread in Illinois of the San Jose scale and other dangerous insects and contagious diseases of fruits, and repealing a certain Act therein named.

SECTION 1. *Be it enacted by the People of the State of Illinois, represented in the General Assembly:* That it shall be the duty of the State Entomologist of Illinois to inspect, or cause to be inspected by his duly appointed assistants, at least once each year between July 1 and September 15, all nurseries and nursery premises in the State of Illinois, as to whether they are infested by dangerous insects or infected by dangerous plant diseases. If upon the inspection of any nursery as above provided it shall appear that said nursery and its premises are free from dangerous insects and dangerous plant diseases, it shall be the duty of the State Entomologist upon payment of the expenses of inspection, and certified by him to give or to send to the owner of said nursery, or to the person in charge of the same, not later than October first, a certificate of inspection stating that said nursery and premises are apparently free from such insects and diseases, and such certificate shall be valid, unless revoked for cause as hereinafter provided, for one year from the date of inspection, and no longer.

The provisions of this section shall not apply to florists' greenhouse plants nor to flowers or cuttings commonly known as greenhouse stock, and no certificate shall be required for the shipment of native stock collected in the United States and not grown in nurseries.

If the State Entomologist shall find that part of a nursery is infested with dangerous insects or infected by contagious plant diseases and that the remainder of it is not so infested or infected, or if he shall have reason to believe that a nursery is liable, by reason of its proximity to infested or infected premises, to become so infested or infected

*Twenty-one thousand dollars (\$21,000) per annum appropriated for 1909 and 1910.

before the next annual inspection, he may prescribe in writing such measures of precaution, or may make in writing such conditions as to the use of his certificate, as may in his judgment be necessary, and he may withhold his certificate until such conditions have been accepted in writing by the owner of said nursery; and the use of such certificate without taking such measures of precaution or observing such conditions shall subject the owner of said nursery to the penalties prescribed in section 5 for a violation of this Act.

Whenever any nurseryman or seller of trees, shrubs, vines, plants, buds, or cuttings commonly known as nursery stock, shall ship or deliver any such stock he shall place and send on each car, box, bale, bundle, package, or piece, a true copy of a valid certificate of inspection, signed by the State Entomologist of Illinois, or by another inspector duly approved by him, showing that the said stock has been carefully inspected and found apparently free from any dangerous insects or dangerous plant disease. Any person who shall deliver, ship, or consign for shipment nursery stock without such certificate attached, or who shall use such certificate in connection with nursery stock any and every part of which has not been inspected and certified as aforesaid, or who shall alter or deface such certificate, or who shall use an imperfect copy of such certificate, shall be liable to the penalties prescribed in section 5 for a violation of this Act.

If the State Entomologist shall find that his certificate of inspection has been used in violation of law, he shall have power to revoke and annul said certificate by written notice to the holder thereof, and such notice shall take effect forthwith, and the use of said certificate after it has been revoked and annulled, and before such revocation has been withdrawn by the State Entomologist, shall subject the holder of said certificate to the penalties provided in section 5 for a violation of this Act.

It shall be the privilege of the nurseryman to ship, under the certificate issued to him, nursery stock grown for him elsewhere or purchased by him from other states or countries: *Provided*, that all such stock be received under a certificate satisfactory to the State Entomologist stating that it has been inspected where grown and found to be apparently free from dangerous insects and dangerous plant diseases. The State Entomologist shall send, once each year not later than July 1, to all nurserymen in the State known to him, a list of official inspectors of other states and foreign countries whose inspection certificates may be accepted in this State, for one year from the date thereof, as equivalent to his own certificate.

Every agent for a nursery outside of Illinois and every dealer not engaged in growing trees, shrubs, plants, or vines, in this State, for sale, who sells or delivers such stock in this State, shall, before delivering the same, place on file in the office of the State Entomologist a statement made under oath before an officer qualified to administer oaths in the locality where he may reside, or, if a non-resident of the State, in the locality where said stock is sold or delivered, that the said stock has been duly inspected and was received by him accompa-

nied with a valid official certificate of inspection or fumigation, a copy of which certificate shall be filed by him with said statement for the approval of the State Entomologist. Upon receipt of said statement and copy of the certificate of inspection the Entomologist shall report to the sender his approval or disapproval of said certificate. If disapproved he shall inspect, or cause to be inspected, the nursery stock to which the said statement applies, and if he shall find said nursery stock to be apparently free from dangerous insects and dangerous plant diseases he shall give or send to the owner thereof, upon payment of the expenses of the inspection, a certificate to that effect, and the delivery of such stock without an accompanying certificate of inspection issued by the State Entomologist or approved by him shall subject the agent, dealer, or other person selling or delivering the same to the penalties prescribed in section 5 for a violation of this Act.

§ 2. That all gardeners, horticulturists, nurserymen, superintendents of public parks, and other growers of or dealers in plants of any kind upon their own lands, upon leased lands or premises, or upon public parks or highways shall free and keep freed all plants, shrubs, trees, vines, cuttings, scions, buds, stocks or other plant parts grown, cultivated, or dealt in by them, from all injurious insects and fungus pests, which are liable to spread from the plants or premises infested to other plants on the public highways or upon lands belonging to other owners, and all plants, shrubs, trees, or parts of such so infested are hereby declared to be a nuisance to be abated as hereinafter prescribed; and their maintenance, after notice as hereinafter set forth, is hereby declared a misdemeanor punishable as provided in section 5 of this Act. If the State Entomologist shall have reason to suppose that any nursery, orchard, fruit plantation, or other property or place in this State, is infested by dangerous insects or infected with contagious plant disease, he shall have power to inspect or to cause to be inspected, from time to time, such nursery, orchard, fruit plantation, or other property, and for the purposes of such inspection he and his assistants are authorized, during reasonable business hours, to enter into or upon any farm, orchard, nursery, garden, storehouse, or other building or place used for the growing, storage, packing or sale of trees, plants or fruits; and if the State Entomologist shall find, by inspection as aforesaid, that any person, firm, or corporation is maintaining a nuisance as described in this section, he shall notify in writing the owner or occupant of the premises containing the nuisance so disclosed of the fact that such nuisance exists. He shall include in such notice a statement of the conditions constituting such nuisance, an order that the same be abated within a specified time, and a direction, written or printed, pointing out the methods which should be taken to abate the same. Such notice or order may be served personally, or by depositing the same in the post office, properly stamped, addressed to the owner or occupant of the land or premises upon which such nuisance exists, and the direction for treatment may consist of a printed circular, bulletin, or report of the State Entomologist or of the Agricultural Experiment Station, or an extract from the

same. If the person so notified shall refuse or fail to abate said nuisance in the manner and within the time prescribed in said notice, the State Entomologist may cause such nuisance to be abated, and he shall certify to the owner or person in charge of the premises the cost of abatement, and if not paid to him within sixty days thereafter the same may be recovered, together with the cost of action, before any court in the State having competent jurisdiction. In case the notice and order served as aforesaid shall direct that any growing plant, shrub, or tree, shall be destroyed, and the owner or grower of such plant, shrub, or tree, shall consider himself aggrieved by such order, he shall have the privilege of appeal, within three days of the receipt of the notice, to the county court of the county in which said property is situated. The appeal shall be made in like manner as appeals are taken to the county court from the judgments of justices of the peace. Written notice of such appeal served by mail upon the State Entomologist shall operate to stay all proceedings until the decision of the county court, who may, after investigating the matter, reverse, modify, or confirm the order of the State Entomologist. Such decision shall then become the order of the State Entomologist, who shall serve the same as hereinbefore set forth, and shall fix a time within which such decision must be carried out. Any person, firm, or corporation failing to obey an order of the State Entomologist, made and served as prescribed in this section, within the period of time therein specified, shall be deemed guilty of a misdemeanor and liable to punishment as prescribed in section 5 of this Act.

§ 3. Whenever any trees, shrubs, plants or vines are shipped from place to place in this State, or shipped into this State from another state, country or province, every car, box, bale, bundle, package or piece thereof shall be plainly labeled on the outside with the name of the consignor, the name of the consignee, and a certificate signed by a state or government inspector showing that the contents have been inspected by such inspector, or by his authority since the first day of July last preceding, and that the trees, vines, shrubs, and plants, there present and therein contained, appear free from all dangerous insects and diseases. Whenever any trees, shrubs, vines, or plants arrive in this State without such certificate plainly fixed on the outside of the package, box or car containing the same, the facts must be reported within twenty-four hours to the State Entomologist by the railroad, express or steamboat company, or other person or persons carrying the same, and it shall be unlawful to deliver any such property until it has been inspected by the State Entomologist or his assistant and by him certified to be free from dangerous insects or contagious diseases. Any person receiving nursery stock brought into this State from outside this State, and not accompanied by a valid certificate as above prescribed, shall at once notify the State Entomologist of that fact, and shall not allow such uncertified stock to leave his possession until it has been inspected and released by the State Entomologist or his assistant. Any agent of any railroad, steamboat or express company or any other person or persons carrying such

property as aforesaid, or any consignee of such property, who shall fail to give notice to the State Entomologist as above required shall be deemed guilty of a violation of this Act, and subject to the penalties prescribed in section 5.

§ 4. Any owner of an orchard or other fruit plantation in bearing condition may apply to the State Entomologist for an inspection of the same with reference to the presence of the San Jose scale or other dangerous insects or plant diseases liable to prevent the sale or lessen the value of his fruits, agreeing in his application to pay in full the expenses of the inspection, and upon receipt of such application and agreement, or as soon thereafter as may be conveniently practicable, the State Entomologist shall comply with such request, and upon receipt of the expenses of the inspection he shall issue to the applicant a certificate to the facts disclosed by the inspection:

§ 5. Any person who shall violate the provisions of this Act with reference to the sale, shipment, delivery, receipt, or transportation of nursery stock, or with reference to the use, alteration, or defacement of a certificate of inspection relating to the same, or who shall remove, without the written permission of the State Entomologist, infested or infected property concerning whose condition he has received official notice from the Entomologist, or who shall maintain a nuisance as described in section 2 of this Act, after notice by the State Entomologist and direction for its abatement, or who shall offer any hindrance or resistance to the carrying out of this Act, shall be adjudged guilty of a misdemeanor, and upon conviction before a justice of the peace shall be fined not less than twenty-five dollars and not more than one hundred dollars for each and every offense, together with all costs of the procedure, and shall stand committed until the same is paid. It shall be the duty of the State Entomologist to furnish to the State's Attorney all information in his possession concerning violations of this Act, and the State's Attorney shall prosecute such violations of this Act, and amounts so recovered shall be paid into the treasury of the State.

§ 6. The office of the State Entomologist shall be established at the University of Illinois, the trustees of which shall provide for him and his assistants such office and laboratory rooms as may be necessary to the performance of their duties. He shall have power to appoint a chief inspector and such assistants as may be necessary to the execution of this Act, and to fix a reasonable compensation for their labors, and their acts, done in pursuance of his instructions, shall have the same validity as his own. He shall certify to the State Auditor the amount of his expenses and the amount of the salaries and expenses of the chief inspector and assistants employed under this Act, and the Auditor shall thereupon draw his warrant upon the State Treasurer for the amount, which shall be paid out of the funds provided for carrying this Act into effect. The State Entomologist shall make to the Governor a biennial report of his operations under this Act, together with a financial statement in detail, and he shall also make each year to the State Horticultural Society, at its annual meet-

ing, a statement showing the Illinois nurseries inspected, the number and kinds of certificates issued, the location and ownership of the premises treated or disinfected by him or his assistants, and the kinds and amounts of property destroyed by him in pursuance of this Act.

§ 7. An Act entitled, "An Act to prevent the introduction and spread in Illinois of the San Jose scale and other dangerous insects and contagious diseases of fruits," approved and in force April 11, 1899, is hereby repealed.

STEPHEN A. FORBES,
Illinois State Entomologist.

Urbana, August 13, 1909.

EXPERIMENTS WITH REPELLENTS AGAINST THE CORN ROOT-APHIS, 1905 AND 1906

The corn root-aphis, a minute, bluish green, sluggish, soft-bodied insect found on the roots of corn, is one of the most destructive and dangerous insect pests of the corn plant. Beginning as soon as the kernel sprouts to suck the sap from the young roots, it may continue its injury without interruption until frost, unless the infested plant in the meantime perishes. It has an enormous power of multiplication, producing, under favorable circumstances, as many as sixteen generations in a season, and it is capable of spreading from field to field rapidly on the wing, many of each generation, except the first of the year, having the power of flight.

Altho a peculiarly sluggish and stupid insect, wholly unable to make its own way unaided, it has always in its service one of the most capable, abundant, active, and persistent of our common insect species. This is the so-called corn-field ant (*Lasius alienus americanus*), in whose charge the corn root-aphis is usually found, and by which its eggs, laid in fall, are carried thru the winter. This corn-field ant has no power of injuring the corn directly, except as it may occasionally, or under peculiar circumstances, devour the softened kernel in the earth, and the root-aphis, left to itself, can not even get access to its food in numbers to do any noticeable harm; but the two in partnership check the growth of the plants, and even kill outright whole fields of corn, the aphis making the destructive attack, and the ant protecting, transporting, and guarding the aphis, and collecting, preserving, and hatching its eggs.

The practical control of this pair of insects is especially important because the injury done to corn, already very heavy, is sure to increase with time. The more generally and continuously corn is grown, and the more the soil deteriorates under continuous cropping, the greater this aphis injury must become. It is hence most serious and threatening in those very parts of our area best adapted to corn, and is much the greatest now in Illinois in the central part of the state, where corn is the principal crop.

Neither of these insects is subject, so far as known, to destruction by parasites or by contagious diseases, the principal natural checks on the multiplication of most other injurious species. About the only natural agency which can be depended on to reduce the numbers of the corn root-aphis is a long-continued soaking of the ground by frequent heavy rains, especially if these come in a slow, cool spring. The very wet spring of 1907, for example, seems to have had the effect to

drown out the root-lice and also, to some extent, the maggotlike young of the ants under ground; and some fields heavily enough infested in April and early May of that year to make a profitable crop very unlikely, were completely cleared of root-lice by the beginning of June, and contained unusually few ants.

Our later work on the ant-aphis problem has been done mainly on two lines. We have attempted to test, by field experiments, the value of a repeated deep and thoro stirring of the soil previous to planting, and we have experimented with offensive applications to the seed, of a kind to last a considerable time in the ground, and to keep the ants, and consequently the aphids, out of the hills as long as possible while the plant was still young and especially sensitive to injury. Experiments of the first class were reported in Bulletin 104 of the Agricultural Experiment Station published in October, 1905, and again in the Twenty-fourth Report of the State Entomologist, pages 8 to 29; but those with repellents applied to the seed in 1905-06 are here fully reported for the first time.

REPELLENT APPLICATIONS TO THE SEED

My attention was first called to the fact that applications to the seed might serve to protect young corn against root-louse attack by statements occasionally made by farmers who had treated their seed-corn with kerosene or turpentine just before planting.* Having, I must confess, very little faith in this treatment, I nevertheless directed an assistant, Mr. E. O. G. Kelly, in charge of my field work in 1905, to test the effect of kerosene used in this way, and as part of a general field experiment for the protection of corn against aphis injury, he planted a small plot in an experimental field with seed which had been soaked in kerosene for half an hour.

The effect of this treatment was a double surprise to us. In the first place, only about half as much of the corn grew as in other experiments made in the same field with seed from the same lot, serving, consequently, as checks on this; the other half swelled up with the moisture absorbed, but never sprouted. Furthermore, germination was delayed, growth of the young corn was slow at first, and many of the plants were dwarfed and crippled, the growing tip or plumule of the plant making its way with great difficulty out of the inclosing sheath (the coleophyl) which protects it as it grows upward thru the earth. In the second place, altho the field of corn of which this planting was a part was heavily infested and noticeably injured by the corn root-aphis, this special plot, when examined some weeks after planting, was found to be almost wholly free from the aphis, and to contain but few ants; and at husking time its yield equaled in quantity and excelled in quality that of like areas in other parts of the same field. The treatment of the seed had evidently so repelled the ants

*See especially my address on the corn root-aphis in the Tenth Report of the Illinois Farmers' Institute, p. 49.

and aphids that protection from their injury had more than compensated for the original poor stand. It thus became our problem so to modify this treatment as to get the beneficial result without risk of the injury.

It was evident enough that kerosene merely applied to the seed could act only by reason of its persistent odor—peculiarly offensive to ants—and it seemed quite probable that corn might be so treated with this or some other strong-smelling substance that ants would be kept out of the hills for a considerable time and that the seed would not be injured. As a test of substances possibly useful for this purpose, a long series of experimental plantings was made, from June to August, 1905, and from February to July, 1906, in the field, at Urbana, and in the insectary connected with my office there, and a careful record was kept of the percentage of kernels germinating in each planting, and of the condition of the corn plants for several days after they appeared above ground. The substances thus tested as to their effects on corn were kerosene, kerosene emulsion, crude petroleum, turpentine, carbolic acid, formalin, oil of lemon, oil of wintergreen, oil of cloves, oil of sassafras, wood alcohol, common alcohol, coal-tar, coal-tar water, carbon bisulphid, chlorid of lime, kainit, flowers of sulphur, lime, salt, various compound solutions of sulphur, lime, and salt, and of sulphur, lime, and blue vitriol, copper sulphate, iron sulphate, mustard, camphor, musk, lysol, tobacco-water, the proprietary insecticides known as "Scalecide," "Con Sol," "Calcothion," and "Fruitolin," and the so-called "Rex Dip."

PLOT EXPERIMENTS, 1905

For this purpose the use of a plot of ground was obtained in June, 1905, on the farm of the Experiment Station at Urbana, on which the corn was planted in rows by hand, usually two grains to the hill. Fifteen thousand five hundred kernels were planted in this plot, 5750 of them after treatment with kerosene, 2050 with kerosene emulsion, 2000 with tar-water, 3650 with turpentine, and 2050, with no special application, serving as checks. The principal plantings were those made June 15, of 1500 kernels, and June 28, of 12,500 kernels. Smaller additional plantings, varying from 50 to 1000 kernels, were made June 29 and 30, July 18 and 21, and August 9.

The results of the planting of June 15 were determined by an inspection June 26, and those of June 28 were determined July 20—the first, eleven days after planting and the second after twenty-two days. The weather of these two intervals differed materially, that between June 15 and June 26 being rather dry, and that between June 28 and July 20 decidedly wet—a fact to be borne in mind at some points in comparing the two series of experiments. The ground must have been fairly moist, however, June 15, since a rain of 1.05 inches had fallen on the 10th, but the only rain to fall during the eleven days following June 15 was .06 of an inch on the 20th. Between the 28th of June and the 20th of July, on the other hand, rain fell on sixteen days, to

the total amount of 5.34 inches—that of one day, July 5, amounting to 1.44 inches.

Treatment of seed with kerosene.—The seed-corn experiment with kerosene was so varied as to bring into comparison the results of simply dipping the seed and planting immediately afterwards, and of soaking it for 5 minutes, 10 minutes, 20 minutes, and 30 minutes, and for 11 days, 20 days, and 41 days. Tests were likewise made of the effect of first soaking the seed in water before putting it into kerosene.

The checks to these experiments—2050 kernels which were planted in ten lots of 50 to 500 kernels each at several dates between June 15 and July 21—germinated in ratios ranging from 83 to 96 percent, with an average of 89; and with this average, of course, the germination ratios of the various experiments are to be compared.

Eight experimental lots, containing 2225 kernels in all, received the simplest treatment—a mere dipping in kerosene immediately before planting. The ratios of germination for seven of these lots varied from 84 to 97, with an average of 91. The eighth lot, of only 50 kernels planted in earth kept continuously moist, gave a germination ratio of 62 percent, and including this the average for the series is 87.6. It may fairly be said, consequently, that injury by this treatment was practically imperceptible, but that a suspicion is created of possible damage to the seed if the weather is continuously wet after planting.

Eight lots of seed, numbering 2225 kernels in all, were soaked in kerosene for 5 minutes just before planting. Here also no perceptible damage was done to the seed, the germination ratio amounting to 88.8, to be compared with 89 for the checks.

Of eleven additional lots, averaging 100 kernels each, soaked in kerosene for periods varying from 10 to 30 minutes, 85.2 percent grew, the ratios ranging from 78 to 96. We begin to see here evidences of slight but obvious injury to the seed as a consequence of the treatment. It is nevertheless puzzling to find that 89 kernels grew out of 100 kernels soaked for 11 days, and that 86 percent of 50 kernels soaked for 20 days and 80 percent of the same number soaked for 41 days, also grew.

In many of these kerosene experiments, even tho the kernels sprouted eventually and plants appeared above ground, the germination was much retarded and the plants were more or less distorted and deformed—an effect returned to on a later page of this article.

Kerosene emulsion.—For some obscure reason the result of the treatment of 400 kernels with kerosene emulsion June 15, was very much less favorable than that of 1500 kernels planted June 28. In the first experiments the seed was soaked for 30 minutes in emulsion diluted to contain 10 per cent, 20 percent, 40 percent, and 50 percent of kerosene, with the effect to give a germination ratio, eleven days after planting, of 46 percent for the first, 76 for the second, 63 for the third, and 57 for the fourth of these lots, or an average of 60.5 percent to grow from these plantings. June 28, emulsions were used containing 10, 20, and 40 percent of kerosene, in which corn was soaked for 30 minutes, each of three lots containing 500 kernels. The percent-

ages to grow varied from 91.6 to 95.8, with an average of 93. I am unable to explain these discrepancies, and consequently can not attach any especial importance to these experiments with kerosene emulsion.

Turpentine.—A like discrepancy appears in the turpentine experiments, four plantings for which were made June 15, and six plantings June 28. The first, of 100 kernels each, averaged $56\frac{1}{2}$ percent to grow, and the second, of 500 kernels each, averaged 88 percent. In the plantings of 100 kernels made June 15 immediately after dipping in turpentine, 28 percent grew; while of another hundred soaked in turpentine for 5 minutes, 76 percent grew. Of a third lot, soaked for 10 minutes, 95 percent grew; and of the last lot, soaked for 30 minutes, but 27 percent grew. These variations are so unaccountable and confusing as to vitiate this experiment.

On the other hand, the results of the six plantings of June 28 varied only from 85 to 90 percent, and these results may be fairly accepted. Of 500 kernels dipped in turpentine and planted at once, 90 percent grew; of those soaked for 5 minutes before planting, 88 percent grew; and of those soaked for 20 minutes, 90 percent grew. Of another lot of 500 kernels, soaked first in water for 10 minutes and then merely dipped in turpentine, 90 percent grew; of a second lot treated in the same manner except that they were soaked for 5 minutes in turpentine, 85 percent grew; and the same ratio was obtained from a third lot similarly treated except that the kernels were soaked for 20 minutes in water. This treatment with turpentine may be said, on the whole, to have been apparently without injurious effect, since the check plantings of this date gave a germination average of 89 percent, while the later plantings with turpentine averaged 88 percent to grow.

Tar-water.—Two thousand kernels were planted June 28, after treatment with coal-tar water obtained from the bottom of a gas tank, or from the top of a tank of coal-tar, at the gas works. One thousand of these kernels, merely dipped in the tar-water, gave a germination ratio of 94 percent, and of another thousand soaked in it for 5 minutes, 88 percent grew.

The principal data of the foregoing discussion are summarized in the following table.

PLOT EXPERIMENTS WITH REPELLENTS, 1905

No Treatment of Seed. Check Plots			
Date	Treatment	No. of kernels	Percent to grow
June 15	None	200	88
" 28	"	1500	89
" 29	"	200	83
July 21	"	150	95
General average of checks.....			89

Seed treated with Pure Kerosene

Date	Time in kerosene	No. of kernels	Percent to grow
June 15	Dipped.....	100	95
" 28	".....	1000	97
" 15	5 minutes. Dry.....	100	88
" 28	" " ".....	1000	94
" 28	" " Wet.....	1000	91
" 15	10 " Dry.....	100	85
" 15	20 " ".....	100	87
" 15	30 " ".....	100	82
" 28	30 " Wet.....	500	81
" 30	11 days.....	100	89
July 18	20 ".....	50	86
Aug. 9	41 ".....	50	80
General average of kerosene treatments.....			88

Seed treated with Kerosene Emulsion

Date	Percent kerosene	Time in emulsion	No. of kernels	Percent to grow
June 15	10	30 minutes.....	100	46
" 15	20	30 ".....	100	76
" 15	40	30 ".....	100	63
" 15	50	30 ".....	100	57 60.5
" 28	10	30 ".....	500	92
" 28	20	30 ".....	500	92
" 28	40	30 ".....	500	96 93½

Seed treated with Turpentine

Date	Time in turpentine	No. of kernels	Percent to grow
June 15	Dipped.....	100	28
" 15	5 minutes.....	100	76
" 15	10 ".....	100	95
" 15	30 ".....	100	27 56.5
" 28	Dipped. Dry.....	500	90
" 28	" Wet.....	500	90
" 28	5 minutes. Dry.....	500	88
" 28	5 " Wet.....	500	85
" 28	20 " Dry.....	500	90
" 28	20 " Wet.....	500	85 88

Seed treated with Coal-tar Water

Date	Time in tar-water	No. of kernels	Percent to grow
June 28	Dipped.....	1000	94
" 28	5 minutes.....	1000	88

POT EXPERIMENTS, 1906

In all the experiments of 1906, Leaming seed-corn of excellent quality was planted, at a depth of an inch, in good black soil contained in ordinary earthen flower-pots seven inches across, and kept in the insectary of my office building at Urbana. Temperature and moisture conditions, being under strict control, were made as nearly those of a normal spring as possible. Thirty-five check lots of 50 kernels each (1750 kernels in all) were planted with untreated seed in the course of these experiments. Sixteen hundred and eighty of these kernels germinated, and this germination ratio (96 percent) may be used for comparison in determining the effect of our various applications to the seed.

Kerosene.—Kerosene was used in two ways in these experiments: (1) by mixing it thoroly with the seed in quantities varying from $\frac{1}{8}$ of a fluid ounce to $3\frac{1}{3}$ ounces for each gallon of corn; and (2) by putting the seed into kerosene and soaking it there, previous to planting, for periods varying from 10 minutes to 19 hours. The main results of these various experiments were as follows:

Of 800 kernels planted after stirring in kerosene thoroly, at rates varying from $\frac{1}{8}$ of an ounce to 2 ounces for each gallon of corn, 98 percent germinated, and only 2 of the plants showed any trace of injury. Fifty kernels of this lot, treated at the rate of 2 ounces of kerosene to the gallon, all sprouted, and none of these plants were injured. Furthermore, of 200 kernels treated with kerosene at the rate of $2\frac{1}{3}$ to $3\frac{1}{3}$ ounces to the gallon of corn, 92 percent germinated, and only 3 plants gave any appearance of injury. It would naturally be inferred from this experiment that at least an ounce (two tablespoonfuls) of kerosene to the gallon of corn might be safely used under conditions as favorable as those in our management, but we shall later find evidence, in the outcome of a field experiment made the following spring, that only half this amount injured corn slightly, but still appreciably, under the weather conditions of 1906.

Soaking the corn in kerosene for 10- to 20- minute periods, 200 kernels in each experiment, gave a germination ratio of 88 percent for the first and 93 percent for the second, but with the appearance of injury to 77 percent of the plants in the 10-minute lot and of 80 percent in the 20-minute lot. Furthermore, the plants which grew, averaged only $2\frac{3}{4}$ inches high fifteen days after planting, while 100 plants from untreated seed averaged $6\frac{1}{3}$ inches. The corn would perhaps have outgrown this backset, and might have made a crop, if planted out-of-doors, better than the average in the field, provided that the latter was injuriously infested by the corn root-aphis.

Soaking seed in kerosene for periods varying from 4 hours to 19 hours gave variable results, as reported by Mr. Kelly. Only 1 out of 50 grains (2 percent) soaked for 4 hours had sprouted at the end of thirteen days, while 164 kernels out of 200 (82 percent) which had been soaked for 16 hours before planting, appeared above ground

within six days, 92 percent of the plants finally showing more or less injury. On the other hand, but 3 out of 100 kernels soaked for 19 hours in kerosene were in condition to grow, and all the plants from these 3 were injured.

Perplexing discrepancies of this sort were of rather frequent occurrence in these experiments, and showed that one must apply the results with caution, keeping well within the limits of variation. In view of the observed effect of an overdose of kerosene on the young plant, as described in the earlier part of this article, it is important to note that no dwarfing or distortion of the corn plants was seen in any of these experiments.

Crude Petroleum.—A series of tests made with 600 kernels of corn by soaking them in crude petroleum for various periods ranging from 5 minutes to 74 hours, gave us reason to believe that this substance was too dangerous to be used in this way. No experiments were made, however, with the mere mixture of minimum quantities of petroleum with a gallon of corn. The same variable and discrepant results were reported here as in the experiments with kerosene, 14 kernels growing out of 50, for example, which had been soaked for 30 minutes, and 46 out of 50 which had been soaked for 19 hours. After 5 minutes' soaking, only 42 kernels grew out of 50 planted, and 8 of the plants which appeared were injured.

Oil of Lemon.—A good quality of oil of lemon,* as obtained at a local wholesale drug-store, was used in solution with ordinary alcohol at strengths of 1 part in 10 or 1 part in 3 of the oil to the alcohol. The seed was soaked in these mixtures for periods varying from 5 minutes to an hour. Two plantings were made with kernels treated by stirring 3 ounces of the 10 percent solution thoroly into a gallon of the seed. Of 450 kernels treated in the various ways described, 95 percent germinated with virtually no injury to the plants.

The only damage done to the seed in experiments with this mixture of lemon oil and alcohol appeared in two lots of 50 kernels each soaked in the 10 percent solution, one of them for 20 minutes and the other for 19 hours. In the first of these lots 16 kernels, and in the second lot 21 kernels, failed to grow. It was a perplexing fact that serious injury to the seed was thus reported by Mr. Kelly to have followed the use of a 10 percent solution for 20 minutes, while no harm resulted from a 10 percent solution applied for 30 minutes or for an hour, or from a 33 percent solution applied for 20 minutes or for 30 minutes. It appeared safe to conclude, however, that a 10 percent solution used merely to moisten the seed, say, at the rate of 3 ounces to the gallon of corn, might be applied without risk of injury to the seed; and our field experiments were made, later in the season, on this basis.

Other vegetable oils.—Oil of wintergreen, oil of cloves, and oil of sassafras were tested, each with 400 kernels, divided into eight

*The brand and manufacturer of this sample could not be learned later, when it became important to know just how the results of these experiments were obtained.

experiments. All proved to be too frequently injurious to the seed to make it safe to trust to them—the oil of cloves the most injurious and the oil of wintergreen the least so. Solutions of less than 10 percent strength were not used, however, and no trial was made of any milder form of application than soaking the seed for 5 minutes in an alcoholic solution of the oil. It is possible, consequently, that a simple stirring into the seed of minimum quantities of a 5 or 10 percent solution, as in the case of the oil of lemon, might have been harmless—excepting, however, the oil of cloves, which killed from 44 to 100 percent of the kernels in each experiment.

Carbolic Acid.—The action of carbolic acid was tested by soaking seed-corn from 5 to 30 minutes in solutions of the commercial acid in water, varying in strength from 2 to 30 percent. No injury was done by either 2 or 5 percent solutions applied to lots of 200 kernels each for 5, 10, 20, or 30 minutes, but the 10 and 30 percent solutions killed virtually all the seed even when applied for only 5 minutes. In our subsequent field experiments a 3 percent solution only was used, and then at the rate of 3 ounces of the solution to a gallon of corn.

Formalin.—A few experiments made with formaldehyde, in water solutions of 4 percent, 25 percent, and 50 percent, showed that at 4 percent this substance was harmless to seed-corn soaked in it for any period between 5 minutes and half an hour. Two hundred kernels thus treated gave a germination ratio of 94 percent. The plants which grew, on the other hand, averaged only $4\frac{1}{4}$ inches at a time when the single check of 50 plants averaged 6 inches. The higher strengths mentioned were both extremely injurious, the 25 percent mixture killing from one fourth to four fifths of the seed, according to the period of use, and the 50 percent mixture, applied for half an hour, killing it all.

The Alcohols.—To distinguish between the effects of alcohol and oils in some of the above mixtures, 200 kernels were soaked in common alcohol for periods ranging from 5 minutes to half an hour, and 200 more in wood alcohol from 5 minutes to an hour, with the result that no injury was done except by the longer periods of treatment. From 98 to 100 percent of the grains grew after soaking 10 or 20 minutes in ordinary alcohol, but only 66 percent after 30 minutes' treatment; and 95 percent grew after 5 or 10 minutes in wood alcohol, but only 74 percent after 20 minutes and 14 percent after an hour. From this it may be inferred that seed-corn is uninjured by as much as 10 minutes' soaking in either kind of alcohol, but that more than this is dangerous, and that injury will begin to appear after 20 or 30 minutes' treatment—sooner if the solvent is wood alcohol.

Lysol.—This highly odoriferous coal-tar product was applied to seed-corn in twenty-one lots of 50 kernels each, and in aqueous solutions of 1 percent, 2 percent, 5 percent, and 10 percent, the corn being soaked in each of these 5 minutes, 10 minutes, 20 minutes, and 1 and 2 hours. Another lot of corn was soaked for 5 minutes in pure lysol, and lysol was applied to seed-corn at the rate of half an ounce

of the fluid to the gallon of corn, and at the rate of an ounce to the gallon. No injury was done by the 1 percent solution applied in periods up to two hours, and the 2 percent solution was harmless up to 20 minutes. Two hours' soaking at the latter strength was injurious, giving a germination ratio of but 68 percent, and all the plants growing were more or less injured. The 5 percent solution did no harm when used for 5 or 10 minutes, but after 20 minutes' treatment only 78 percent of the kernels grew, while after 2 hours' treatment at this strength all the corn was dead. Even 5 minutes' use of a 10 percent solution proved injurious. Corn treated with the pure lysol at the rate of half an ounce to a gallon of the corn was uninjured, 92 out of 100 kernels of it germinating; but when this strength was doubled, the germination ratio fell to 73 percent. From these experiments we may infer that a 2 percent solution of lysol in water may be used to soak the seed if treatment be not continued over 10 minutes, and that half an ounce of the undiluted lysol may be stirred into a gallon of corn without risk of injury.

Kainit.—The potash fertilizer known as kainit, which has sometimes been recommended as a repellent to the corn root-aphis, was tested on 300 kernels divided into six lots. The total germination ratio was 90 percent. One lot, in which the planted seed was thickly covered with kainit, fell to 78 percent.

Lime, Sulphur, and Salt.—Saturated solutions of either lime or salt were harmless to seed-corn soaked in them for 30 minutes or less, and 84 percent of the kernels germinated when planted after rolling in a plaster of wet salt, none of the plants showing injury. Simple powdered sulphur, 1 or 2 pounds to the bushel of corn, had no effect upon the seed, however it was applied; neither did mixtures of lime, sulphur, and salt, or lime, sulphur, and blue vitriol, unless these were applied for more than an hour. After 2 hours' soaking in a solution of lime and sulphur (15 pounds of each to 50 gallons of water), seed-corn sprouted in a ratio of 80 percent, with an appearance of injury to all the plants which grew. A ready-prepared solution of sulphur sold under the name of "Rex Dip" was variously used in the treatment of seed-corn, and in every case without noticeable effect on the germination of the seed until this had been soaked in it for more than an hour. Seven hundred kernels divided into fourteen lots of 50 each and soaked for periods varying from 5 minutes to an hour gave a general germination average of 96 percent, 4 percent more than the normal for untreated corn of this sample. Two hundred kernels planted in four lots of 50 each, and soaked for 2 hours, gave a ratio of 88 percent of kernels germinating.

Chlorid of Lime.—Used in a saturated solution, or applied by rolling the kernels in a wet plaster, chlorid of lime was without effect on the sprouting of the seed or the growth of the plants. Two hundred kernels soaked for 5 to 30 minutes in the solution grew in a ratio of 98 percent, and 100 kernels rolled in a thin paste of the wet lime all grew. Dry chlorid mixed with the seed was also harmless to 50 kernels.

Carbon Bisulphid.—A carbon bisulphid treatment was also harmless so far as tested by stirring the undiluted fluid into the corn at the rate of 2 and 4 ounces per gallon, or by soaking the seed in the fluid for 10 minutes.

Copper Sulphate.—Seed-corn soaked in a saturated solution of blue vitriol was uninjured after 5 and 10 minutes' treatment, and 90 percent of the seed germinated after 20 minutes' soaking, but only 83 percent after 30 minutes (16 percent of the plants being injured) and 80 percent after an hour, all of these last plants showing injury.

Iron Sulphate.—Two hundred kernels of seed-corn soaked in a saturated solution of copperas for periods varying from 5 minutes to 16 hours, and in lots of 50 kernels each, were uninjured as to germination, averaging 95 percent.

Tobacco-water.—Strong solutions of tobacco-water, obtained by boiling the stems, did no injury to seed or plant, even when the corn was soaked from 1 to 24 hours. Three hundred and fifty kernels thus treated, 100 of them for the longer period, gave an average germination ratio of 98 percent.

Musk.—Commercial Tonquin musk, mixed with wood alcohol at the rate of 1 part of musk to 10 of the solvent, did no injury to the seed when 3 ounces of the mixture were thoroly stirred into a gallon of corn. Neither a 5 percent nor a 10 percent solution of the musk in ordinary alcohol injured the seed after 5 minutes' soaking, but a longer exposure diminished the ratio of germination, and soaking for an hour was decidedly injurious. These effects were, however, quite possibly due to the alcohol.

Mustard.—Mustard was injurious when applied in the powdered form, but 16 hours' soaking in a saturated solution with water did not affect germination.

Miscellaneous substances.—The proprietary insecticides "Scalecide," "Con Sol," "Calcothion," and "Frutolin" were all without effect upon the seed, tested by soaking the seed in them for 5 to 30 minutes. "Scalecide" was used in 5 and 10 percent mixtures with water, "Con Sol" in a 2½ percent mixture, and "Calcothion" and "Frutolin" pure. Twenty lots, amounting to 1000 kernels, were soaked in these various insecticides, none giving less than a germination ratio of 92 percent, and most of them rising to 98 and 100 percent.

Fifty kernels of corn left in coal-tar for a minute and planted at once, all grew but one—very slowly, however, and with more or less appearance of injury, the plants averaging only 3⅓ inches in height four weeks after planting. Soaked in coal-tar for 16 hours, only 11 kernels grew out of 50, and the plants from these were all stunted and otherwise injured.

Tar-water, obtained by pouring water upon coal-tar and stirring the two together and leaving for a time to settle, did no injury to 50 grains of seed soaked for half an hour or an hour.

Camphor was imperfectly tested by soaking seed-corn for 10 minutes and for an hour in a saturated solution of the gum in alcohol.

After 10 minutes' soaking all the seed grew, but after one hour's treatment all but 2 kernels out of 50 were killed. A light application of the solution at the rate of about 3 ounces to the gallon of corn produced no effect, 49 kernels out of 50 growing, and the plants being uninjured and of maximum height after 3 weeks.

The more important of these statistical data are brought together in the table following.

PRINCIPAL POT EXPERIMENTS WITH REPELLENTS, 1906

No Treatment of Seed. Check Pots

	No. of kernels	Percent to grow
No treatment	1750	96

Treatment of Seed with Kerosene

Quantity or time	No. of kernels	Percent to grow
$\frac{1}{8}$ oz.—2 oz. to one gallon	800	98
$2\frac{1}{3}$ oz.— $3\frac{1}{3}$ oz. to one gallon	200	92
10 minutes' soaking	200	88
20 " "	200	93
4 hours' "	50	2
16 " "	200	82
19 " "	100	3

Treatment of Seed with Crude Petroleum

Time in petroleum	No. of kernels	Percent to grow
5 to 10 minutes	100	91
20 to 30 "	100	56
1 to 3 hours	150	77
19 to 74 "	250	54

Treatment of Seed with Oil of Lemon and Alcohol

Quantity or time	No. of kernels	Percent to grow
Oil of lemon, 10% mixture:		
3 oz. to gallon of corn	100	98
20 to 60 minutes' soaking	150	87
19 hours' soaking	50	58
Oil of lemon, $33\frac{1}{3}$ % mixture:		
5 to 10 minutes' soaking	100	99
20 to 30 " "	100	99

Treatment of Seed with Solutions of Carbolic Acid

Strength	Time	No. of kernels	Percent to grow
2 percent	5 to 30 minutes.....	200	99
5 " "	5 to 30 " ".....	200	96
10 " "	5 to 30 " ".....	200	9
30 " "	5 to 30 " ".....	200	1

Treatment of Seed with Formalin Solutions

Strength	Time	No. of kernels	Percent to grow
4 percent	5 to 30 minutes.....	200	94
25 " "	5 minutes.....	50	74
25 " "	10 to 30 minutes.....	150	34
50 " "	30 minutes.....	50	0

Treatment of Seed with Alcohol

	Time in alcohol	No. of kernels	Percent to grow
Common alcohol:			
	5 to 20 minutes.....	150	98
	30 minutes.	50	66
Wood alcohol:			
	5 to 10 minutes.....	100	95
	20 minutes.....	50	74
	60 " ".....	50	14

Treatment of Seed with Lysol in Water

Strength	Time or quantity	No. of kernels	Percent to grow
1 percent	5 to 120 minutes.....	200	99
2 " "	5 to 20 " ".....	150	95
2 " "	2 hours.....	50	68
5 " "	5 to 10 minutes.....	100	96
5 " "	20 minutes.....	50	78
5 " "	2 hours.....	50	0
10 " "	5 to 10 minutes.....	100	78
10 " "	20 to 60 " ".....	100	0
100 " "	5 minutes.....	50	2
100 " "	1 oz. to gal. corn.....	100	73
100 " "	½ oz. to gal. corn.....	100	92

A CORN-FIELD EXPERIMENT, 1906

Precautions preliminary to a large field experiment having been thus taken, and injury to the seed thus guarded against, the way was open to a practical test of the most promising of these repellents, to be made by planting parts of the same field with corn treated with each of them, leaving other parts untreated as a check.

THE EXPERIMENTAL FIELD

For this purpose, after a careful examination of many fields in the vicinity of Elliot, Ford county, by one of my assistants, Mr. E. O. G. Kelly, choice was made of twenty acres of dark rich loam, level and of a uniform quality, on the farm of Mr. James Jones, one and a half mile northeast of Elliot.

This ground had been in corn the preceding year, and it was heavily infested by the corn-field ant. The old stalks were harrowed down and burned April 24 and 25, and the field was plowed to a depth of 4 to 6 inches April 26 to 28, with a gang of two plows, each cutting a furrow 15 inches wide. It was then twice harrowed with a toothed harrow—the last time May 7—and was planted May 8 to 11, in rows 80 rods long, 372 hills to the row, the hills $3\frac{1}{2}$ feet apart each way.

INSECT INFESTATION OF FIELD

A number of ants' nests in this field, critically examined previous to April 26, all contained eggs and recently hatched young of the corn root-aphis. The degree of infestation of the field was ascertained by counting the nests of the corn-field ant overturned by the plow. Eleven hundred and forty-two nests were found in 62 furrows crossing the field and aggregating $15\frac{1}{2}$ miles in length. This was at the rate of 74 ants' nests to the mile of furrow, 516 to the acre, or 10,320 to the entire field.

Nineteen days later 250 hills of the corn in the check plots of this field were found to harbor an average of 62 ants to the hill,—equivalent to nearly five millions in the entire field; and within six weeks from the time of planting, the check hills averaged 162 root-lice,—equivalent to twelve and a half millions of those insects to the field.

Even this statement does not fully describe the burden of infestation with which our experimental field began the year. During his tramp of $15\frac{1}{2}$ miles, backward and forward behind the plow, Mr. Kelly counted also 6519 white-grubs exposed in plowing, which is at the rate of nearly 3000 of these destructive insects to the acre, or 59,000 for the entire field. Of course only a small part of the grubs in the soil were brought to view by the plowing, and this number may reasonably be trebled or quadrupled for an estimate of the whole number present.

DESCRIPTION OF THE EXPERIMENT

The ground being thus selected, found thus infested, and made ready for planting, an experiment was started May 9 with four principal substances—kerosene, oil of lemon, formalin, and carbolic acid—and with three others, to which less importance was attached—flowers of sulphur, chlorid of lime, and "Rex Dip." The experiment was laid out as follows:

The first 50 rows from the east side of the field were planted with corn not treated, and available, consequently, as a check. The next 24 rows were planted with seed treated with a 3 percent solution of

crude carbolic acid in water. Three ounces of this mixture was poured upon a gallon of corn, which was thoroly stirred until every kernel was moistened, the surplus being allowed to drain away. Notwithstanding its slightly moist condition, the corn ran out of the planter as well as if it had been dry.

The 20 rows next this strip were planted with ordinary seed left as a check; and for the next 12 rows the corn was treated with kerosene, half a fluid ounce of the pure oil being thoroly mixed with a gallon of the seed just before it was put into the box.

The next 12 rows were planted with corn treated with oil of lemon. For this purpose one part, by measure, of the oil was mixed with nine parts of ordinary alcohol, and 3 fluid ounces (6 tablespoonfuls) of this solution was thoroly stirred into a gallon of corn, which was then drained and put at once into the planter box.

The next 8 rows were left as a check; and for the plot of 12 rows adjoining, the seed was treated with formalin reduced to a 3 percent solution by the addition of water. Three ounces of this mixture was thoroly stirred with a stick into a gallon of corn, which was then carefully drained and put into the planter at once.

On the 11th of May, in another part of the field, 28 rows of corn were planted, the seed for which had been treated with a solution of lime and sulphur known as "Rex Dip," 1 part of this substance to 10 parts of water. A pint of the mixture was poured upon a gallon of seed-corn, which was then thoroly stirred and after 20 minutes' soaking the seed was drained, being stirred in the meantime to dry it partially, in order that it might work well in the planter.

Next to this plot a strip of 8 rows was left as a check, and the following 8 rows were planted with corn treated with flowers of sulphur. The grain was dampened slightly to make the sulphur stick, and a quarter of a pound of the latter was stirred thoroly into a gallon of corn, completely covering all the kernels.

Finally, 16 rows adjacent were planted with seed which had been soaked for 10 minutes in half a pint of a saturated aqueous solution of chlorid of lime to the gallon of corn.

The ground was reported to be very dry at the time of planting, and the young weeds in the field were all dead as a consequence. Its condition was evidently not unusual, however, since a heavy rain is recorded for May 2, and another followed May 8.* Nevertheless there was some deficiency of moisture, for the soil was lumpy after plowing, and the sprouting of the seed was said, on the 22d, to have been delayed somewhat by dry weather.

Fifty hills of corn were examined on the latter date in one of the checks, and 15 were found to contain root-lice and ants. Odors of carbolic acid, oil of lemon, and kerosene were still perceptible on the kernels a week after planting, but the corn treated with formalin had no noticeable smell.

*Rains fell at this place as follows: April 8, 13, 24, 30 (shower); May 1, 2 (heavy), 8, 18 (slight), 26 (heavy), 27, and 30. The fields and roads were said to be muddy June 1.

RESULTS OF THE EXPERIMENT. FIRST INSPECTION

The first general inspection of the field was made by Mr. Kelly May 28 to 30, when 800 hills were dug up in the various plots and the ants and root-lice were carefully counted.* Two hundred and fifty of these hills were from the check plots, 100 each from the principal experimental plots—those with carbolic acid, kerosene, formalin, and oil of lemon—and fifty each from the three remaining plots whose seed had been treated with sulphur, "Rex Dip," and chlorid of lime.

Percentages of hills infested 10 days after planting.—At this time, a month after the plowing of the field and 19 days after planting, 57 percent of the 250 hills dug up in the check plots were infested by ants. The corresponding averages for each of the four principal experimental plots were as follows: oil of lemon, 23 percent infested; kerosene, 31 percent; formalin, 33 percent; and carbolic acid, 49 percent. The ratios for the less important experiments, from each of which 50 hills were dug up, were 54 percent for the sulphur plot, 70 percent for the "Rex Dip," and 48 percent for the chlorid of lime. Otherwise stated using the condition of the check plot as a basis of comparison, the plot treated with the oil of lemon showed an improvement of 60 percent in number of hills infested by ants; the kerosene plot, a 46 percent improvement; the formalin plot, 42 percent; and the carbolic acid plot, 14 percent. The three other plots showed no improvement except possibly the chlorid of lime.

Not all the hills containing ants at this time contained root-lice also, but there were no root-lice where there were no ants. The ratios of infestation of corn hills by the root-aphis for the five plots were as follows: checks, 53 percent; oil of lemon, 14 percent; kerosene, 20 percent; formalin, 28 percent, and carbolic acid, 39 percent. The corresponding ratios of improvement in respect to aphis infestation were these: oil of lemon, a benefit of 74 percent; kerosene, 62 percent; formalin, 47 percent; and carbolic acid, 26 percent.

It is a suggestive fact that while the infested hills of the checks contained an average of 21 ant larvæ to the hill, none of the hills treated with the three most odorous substances, oil of lemon, kerosene, and carbolic acid, contained so much as a single larval ant. In the formalin plot, however, there were about as many larvæ to the infested hill as in the checks. As the ants take assiduous and anxious care of their young, the absence of larvæ from the treated hills, even where the workers themselves were numerous, is evidence that conditions there were offensive to the ants.

In view of the observed effect of an overdose of kerosene on the young plant, as described in the earlier part of this article, it is important to note that no dwarfing or distortion of the corn plants was seen in any of these experiments.

Average numbers of insects 10 days after planting.—Turning now to the number of both kinds of insects in these plots, irrespective of

*The owner of this field was paid at an agreed rate for all hills dug up or injured in the course of our experiments.

the number of hills of corn infested by them, we find an average of 66 ants and 23 root-lice to the hill in the checks, 9 ants and 2 root-lice to a hill in the oil of lemon plot, 16 ants and 3 root-lice in the kerosene plot, 30 ants and 6 root-lice in the formalin plot, and 25 ants and 12 root-lice to the hill in the plot treated with carbolic acid. The ratios of benefit in respect to the numbers of root-lice were consequently as follows. With respect to ants: oil of lemon, 86 percent benefit; kerosene, 76 percent; formalin, 55 percent; and carbolic acid, 62 percent. With respect to root-lice: oil of lemon, 83 percent benefit; kerosene, 87 percent; formalin, 74 percent; and carbolic acid, 52 percent. The use of the three secondary applications, on the other hand, "Rex Dip," chlorid of lime, and sulphur, had evidently accomplished comparatively little. In the plot treated with chlorid of lime there were 31 ants and 25 aphids to the hill; in that treated with sulphur, 45 ants and 31 aphids; and in the plot treated with "Rex Dip," 72 ants and 53 aphids—the last two of these numbers being actually greater than those for the checks.

The total normal infestation of this field at this time, as shown by the condition of the checks, was 240,000 ants and 124,000 root-lice to the acre. The aphids were all in hills of corn, while only so many of the ants were there established as was necessary to the purposes of the colony, the central home of which was commonly outside the hill between the rows of corn. The data of the foregoing discussion are briefly presented in the tables on page 20.

RESULTS OF THE EXPERIMENT. SECOND INSPECTION

June 21, 43 days after planting, a second count was made of both ants and aphids in 250 hills—50 hills each for the check and for the four principal experimental plots. At this second counting, 73 percent of the hills in the check were infested with ants, 22 percent of those in the oil of lemon plot, 44 percent in the kerosene plot, 46 percent in the formalin plot, and 76 percent in the plot treated with carbolic acid. A few hills contained ants which did not contain root-lice also. The corresponding ratios of infestation by root-aphids for these five plots were as follows: check, 73 percent; oil of lemon, 20 percent; kerosene, 40 percent; formalin, 46 percent; carbolic acid, 74 percent. In respect to number of insects in each lot of 50 hills dug from the various plots, we find the difference quite as marked. The check plot contained 39 ants and 166 aphids to the hill; the oil of lemon plot, 8 ants and 18 aphids; the kerosene plot, 16 ants and 52 aphids; the formalin plot, 20 ants and 64 aphids; and the carbolic acid, 32 ants and 139 aphids.

Converting these data into percentages of improvement, by comparing the ratios for each experiment with those of the check, we find that the benefit to the plot treated with oil of lemon was 70 percent in number of hills infested by ants, 73 percent in hills infested by aphids, 79 percent in the number of ants in the plot, and 89 percent in the number of aphids. The corresponding ratios of benefit for the

kerosene plot are 40 percent in hills infested by ants, 45 percent in those infested by aphids, 59 percent in number of ants, and 69 percent in number of aphids. In the formalin plot the benefit for hills infested by ants and by aphids was 37 percent for each, and the benefit in number of ants in the plot was 49 percent, and in number of aphids, 61 percent. In the carbolic acid plot, on the other hand, the numbers of hills infested by ants and by aphids were somewhat larger than in the check.

INSPECTIONS OF MAY AND JUNE, 1906

Percent of Hills infested

	Check	Oil of lemon	Kerosene	Carbolic acid	Formalin
By ants:					
After 19 days	57	23	31	49	33
After 43 "	73	22	44	76	46
By aphids:					
After 19 days	53	14	20	39	28
After 43 "	73	20	40	74	46

Insects to the Hill

	Check	Oil of lemon	Kerosene	Carbolic acid	Formalin
Ants:					
After 19 days	66	9	16	25	30
After 43 "	39	8	16	32	20
Aphids:					
After 19 days	23	2	3	12	6
After 43 "	166	18	52	139	64

Percentages of Benefit from various Treatments

	Benefit in hills infested				Benefit in No. of insects			
	After 19 days		After 43 days		After 19 days		After 43 days	
	By ants	By aphids	By ants	By aphids	Ants	Aphids	Ants	Aphids
Oil of lemon	60	74	70	73	86	83	79	80
Kerosene	46	62	40	45	76	87	59	69
Carbolic acid	14	26	00	00	62	52	18	15
Formalin	42	47	37	37	55	74	49	61

FIRST AND SECOND INSPECTIONS COMPARED

Comparing next the conditions found May 28 and June 21, we find that the number of hills infested in the check had increased between these dates from 57 percent to 73 percent for ants, and from 53 percent to 73 percent for the aphids; while the number of ants to the hill had diminished from 66 to 39 and the number of aphids to the hill had increased from 23 to 166. The number of the aphids, it will be seen, had increased sevenfold.

Rate of increase of root-lice in the field.—The period of active multiplication of the root-aphis in the field commonly continues until early October, approximately six times the period within which we found a sevenfold increase. If this rate of increase were maintained until the end of the season, the 124,000 aphids per acre found May 28 would multiply by October 1 to more than 14,340,000,000, or 39,000 to the hill of corn. This computation of the actual rate of multiplication of the corn root-aphis in the field is sufficient to account completely for any amount of injury which these insects may do to the crop under conditions favorable to their increase.

RESULTS OF THE EXPERIMENT. THIRD INSPECTION

On the 17th of July Mr. Kelly reported a conspicuous difference in height between the corn on the experimental strips and that on the checks—a difference so great, indeed, that as one looked across the field, it seemed to lie in alternate ridges and hollows, the ridges corresponding to the experimental strips and the hollows to the checks. The ground being perfectly level, these differences were evidently due to the more rapid growth of the corn in the experimental plots; or, more correctly speaking, to an arrest of growth in the checks resulting from the greater drain of insect injury where the corn had not been protected by a previous treatment of the seed. Visiting this field July 21, I noticed that the central rows of the check strips were shortest, and the central rows of the experimental strips were tallest, the transition from one to the other being gradual. On passing down a central check row, the highest stalks reached, on the average, to my elbows; and on walking down the central row of an experimental strip, the tallest stalks were found to reach nearly to the top of my head.

To verify this observation, measurements were made of the tallest stalks in 214 hills of one of the checks, and in 157 hills of the carbolic acid plot. The first of these averaged 36 inches and the second 62 inches. The height of the corn in the check strip was less by 42 percent than that in the experimental plot, and this was the measure of an injury by insects in the former which had been prevented in the latter by the treatment of the seed. This striking difference was quite as obvious to the eye August 27, after all the corn had tasseled.

RESULTS OF THE EXPERIMENT. FOURTH INSPECTION

What proved to be a final inspection of this field was made September 20, when the hills and both fertile and barren stalks were

counted in six rows of the checks and in three rows each of the four experimental plots.

Number of hills of corn to the row.—The following were the average number of hills of corn to the row 372 hills long. In the check, 329½ hills; in the carbolic acid plot, 328; oil of lemon, 326; formalin, 317; kerosene, 282. In other words, 11.4 percent of the places for hills were without corn in the check, 11.8 percent in the carbolic acid plot, 12.4 in the oil of lemon plot, 14.7 percent in the formalin plot, and 24.2 percent in the plot treated with kerosene. The differences between the check on the one hand and the plots treated with carbolic acid and oil of lemon on the other are doubtless insignificant, and perhaps the formalin plot should be included in this statement. Considerable importance must be attached, however, to the fact that more than twice as many hills were missing in the plot treated with kerosene as in the check, *three* rows of the kerosene plot containing 271 missing hills as against 255 missing from *six* rows of the check. In view of the injurious effect of kerosene upon the seed, as shown by our insectary work and by our field experiment of 1905, we can only suppose that some injury was done even by the minimum amount of kerosene used in this experiment of 1906.

Number of stalks of corn to the row.—The number of stalks to the row in these various plots was as follows: check, 621; oil of lemon, 641; formalin, 545; carbolic acid, 543; kerosene, 511. The plot treated with the oil of lemon, it will be noticed, contained 20 stalks more to the row than the check—an increase of 3.2 percent, apparently due to a complete destruction of the plants by the insects in the check, against which the experimental strip had been protected by its treatment. In the remaining plots, on the other hand, the number of stalks was diminished in the experimental plots from 12.2 percent in the formalin strip to 17.5 percent in the kerosene—a diminution which can only be accounted for on the supposition that a certain amount of the seed was injured by these substances. Indeed, taking as a basis of comparison the number of stalks in the plot planted with seed which had been treated with oil of lemon, we find the loss of plants in the kerosene strip to have been 20 percent and that in the other plots to have been approximately 15 percent—all due, so far as one can see, to injury to the seed by the substances employed.

Ear-bearing stalks to the row.—The most significant comparison of these plots was made by a count of the stalks bearing ears, the number of barren stalks varying greatly according to the treatment applied. In the check plot were 412 ear-bearing stalks to the row; in the oil of lemon plot, 526; in the carbolic acid plot, 505; in the formalin plot, 485; and in the kerosene plot, 439,—all four numbers considerably larger than those of the check. The greatest improvement to be seen in this final test of treatment is in the oil of lemon plot, where the yield in ear-bearing stalks was 27.7 percent greater than that of the check. the corresponding ratios of increase for the remaining plots being as follows; carbolic acid, 22.6; formalin, 17.7;

kerosene, 6.6. It will be noticed that notwithstanding the fact that the kerosene plot contained an average of 110 stalks per row fewer than the check, the number of ear-bearing stalks was 27 per row greater than in the check. Even the kerosene, tho it seemed to have lessened the stand by an injury to the seed, had increased the yield nearly 7 percent by protecting the corn against the drain of root-louse attack, thus preventing the blighting of a considerable percentage of the remaining stalks. Under the conditions present during this season and in this field, all these treatments had an ultimate beneficial result, according to the data thus repeatedly and carefully collected, the actual ratio of benefit being, however, nearly four times as great from the use of the oil of lemon as from the use of kerosene.

INSPECTION OF SEPTEMBER 20

	Check	Oil of lemon	Carbolic acid	Formalin	Kerosene
Hills to the row.....	329.5	326	328	317	282
Stalks to the row.....	621	641	543	545	511
Fertile stalks to the row	412	526	505	485	439

Thru an unfortunate failure of the tenant farmer controlling this field, I was disappointed in my original plan to harvest the plots separately, measuring and weighing the product of each in comparison, and the difference in yield, apart from these differences in number, can only be inferred from Mr. Kelly's note of September 20, which reads: "The ears and the stalks in the checks were very small, much smaller than on any of the treated plots. The ears and stalks in plots treated with oil of lemon and carbolic acid were much larger than those in the other treated plots, and much larger than in the checks."

GENERAL FINAL RESULT

As a final statement of the most important result of the various treatments of seed-corn here described, it may be said that, according to the data of this experiment, the oil of lemon treatment increased the yield 1159 ear-bearing stalks to the acre; the carbolic acid treatment, 945 such stalks; the formalin treatment, 742; and the kerosene treatment, 274.

The expense of all the treatments was trifling, that of the most costly—the oil of lemon—amounting to about ten cents an acre for material used.

COMPARISON OF INFESTED FIELDS

That the infestation of this field altho heavy enough to reduce the yield by at least one third, was not by any means extreme is shown by conditions reported by Mr. Kelly from a field of 20 acres on another farm near Elliot, as shown by an inspection made September 14. This latter field was so heavily infested by the corn root-aphis that the

crop was virtually destroyed. In a plot of 2000 hills were 2467 stalks, of which 95 percent were less than 4 feet high, and 75 percent were 20 inches high or less. In this entire plot were only 95 ears—a number equivalent to 169 ears to the acre—and these were mainly nubbins. Eleven hundred and thirty-eight hills contained still living plants, and in 1093 of them the root-aphis was still present. Four hundred and sixteen hills which were either dead or withered, dry, and barely living, all contained the root-aphis at the time, or showed by the burrows of ants along the roots that they had been previously infested. In a neighboring field practically uninfested, with which this is to be compared, 2000 hills contained 4324 well-grown stalks with 4024 ears, only 201 of which were nubbins.

MORE EXPERIMENTS NECESSARY

Our field experiment of 1906, decisive as it seems, is, of course, to be taken as applying exactly only to similar, if not identical, conditions—a similar soil similarly prepared, equally infested with the corn root-aphis, and subject to similar weather conditions—and with a treatment of seed identical with ours in all particulars, including materials of the same quality and strength. How far the results here described may be expected to apply to a different soil, less heavily, or even much more heavily, infested, more thoroly prepared, and planted during either a very wet spring or a very dry one, with a less perfect seed, treated with slightly different chemicals and compounds, can be learned only by repeated and varied experiment. Indeed, the possibilities of useful experiment with this method are almost innumerable, and can scarcely be exhausted by any one office, however well manned and equipped, and however long its program of operations. The procedure is so simple and so inexpensive, however, that any careful corn grower can test it, and its usefulness in ordinary practice must be finally determined by such general, careful, and oft-repeated trial as farmers themselves may think it worth while to make. It is my purpose to test it by similar operations in several successive years, the results of which will be reported in later articles of this series, and it will greatly help us to an early practical conclusion if others interested will experiment carefully, and report upon their methods, materials, and results.

AN ADDITIONAL, MINOR TEST

Further special tests on the reactions of ants to the various repellents of our list were made by planting, close around burrows of these ants in the field, a few hills of corn, one of which was left untreated as a check, the remainder being treated with one of the repellents as a test. "Rex Dip," formalin, carbolic acid, oil of lemon, kerosene, chlorid of lime, sulphur, and common lime were tested in this way. The hills so planted were thus immediately exposed to infestation, and any failure of the ants to occupy them would be particularly significant. The test plantings were all made by Mr. Kelly April 5.

in a field near Elliot, and the results were ascertained April 22, when the corn was from 3 to 5 inches high. All the test hills surrounding the ants' nests, including both check and experimental plantings, were thoroly infested by ants and root-lice where the seed had been previously treated by rolling it in lime or sulphur, by soaking for 10 minutes in a saturated solution of chlorid of lime, and by soaking for 10 minutes in a 10 percent mixture of the "Rex Dip." In the lime experiment, 5 hills were planted immediately surrounding an ant's nest, one of these being reserved as a check; in the sulphur experiment, 4 hills were so planted; and in that with chlorid of lime, 4 hills. In that with "Rex Dip," 7 hills were planted around 2 separate nests of the ant. The results of these experiments thus agree with those of our more general test of plot plantings in the field.

As a test of the formalin treatment of the seed, 2 ants' nests were surrounded by 7 hills of corn, 3 around one and 4 around the other. In each case one of the hills was planted with untreated seed, and the seed for the others was soaked in a 4 percent solution of formalin,—for those around one nest for 5 minutes, and for those around the other for 10 minutes. After 17 days, both check and experimental hills were all completely and uniformly infested by the ants.

In an experiment with the oil of lemon, 4 hills were planted around another ant nest, three of them with treated grains and one as a check. Here also all the hills were infested May 22.

In a corresponding experiment with kerosene, 10 hills were planted so as immediately to surround 2 nests of the ants, two of these hills being reserved as checks and the other eight planted with corn which had been moistened with kerosene by putting a single drop to a dozen grains and rolling these together until all were oily. By the 22d of May one of these nests was completely abandoned by the ants, which had apparently formed another nest about three feet away. There were no aphids on roots of either check or experimental hills. The other nest was still occupied, and there were a few aphids on the roots of the check, but none of either ants or aphids on the experimental hills.

Finally, two nests were surrounded by 8 hills, 6 of which had been treated with a 3 percent solution of carbolic acid—in the one case soaking for 5 minutes and in the other for 10. In the former case the roots of the check hill were covered with root-lice attended by a few ants, while those of the three experimental hills had neither ants nor aphids on them. In the latter case the ants had abandoned their nest, and neither checks nor experimental hills were infested.

These results differ, it will be seen, from those of the plot plantings in the fact that, while carbolic acid and kerosene apparently kept the insects out of the treated hills for three weeks, oil of lemon and formalin, as well as a number of other substances tested, were without effect.

GENERAL PROGRAM OF PREVENTION

In the light of what we now know concerning the corn root-aphis, the following measures of precaution are to be recommended as a practical program.

1. *A short rotation period in corn, especially during relatively dry years.* A single year in corn is better than two years, and a period of two years is better than one of three. Especially if the crop was visibly injured by the root-aphis the preceding year, or if more than twenty ants' nests to the mile are turned up by the plow, it is best that the field should be put into some other crop than corn—which other is a matter of indifference, since no other is liable to injury by the corn root-aphis.

It must be remembered, however, that even a field in corn for the first time may become infested during the season by means of winged root-lice coming into it from other fields in its neighborhood, this infestation perhaps beginning as soon as the corn is up; and that the rate of multiplication of these insects is so enormously rapid, under favorable conditions, that such a new infestation sometimes reaches destructive numbers before the first season is over. Even the shortest rotation is consequently not a complete preventive where the root-aphis has become so generally prevalent as it now is in most parts of the Illinois corn belt. This is, however, the most reliable of all known measures of prevention, and has the very great additional advantage that it affords complete protection against another of the great insect pests of the corn field, the notorious northern corn root-worm (*Dia-brotica longicornis*).

2. *A deep, thoro, and repeated stirring of old corn ground in fall or spring (or, better still, in winter, where possible) as a preparation for corn-planting.* So quick a rotation as that advised in the preceding paragraph is perhaps not always practicable, and is at any rate often unwelcome and will not always be practiced. If corn is to be planted on ground more or less infested by the root-aphis the preceding year, injury by this insect may be greatly diminished by such a preparation of the soil as will repeatedly break up the underground nests of the ants and scatter the contents of these nests, consisting of the eggs and young of the ants together with the root-lice and their eggs, thoroly and repeatedly thru the dirt. The burrows of these ants do not often reach to a depth of more than six inches, and if plowing to this depth is followed by a deep stirring of the ground with a disk harrow, or better, with a corn cultivator set into the ground as far as possible, the attempts of the ants to recover their property and to reconstruct their nests are greatly disturbed and rendered largely fruitless. The more thoroly, frequently, and deeply the ground is stirred in the interval between the first plowing and the corn-planting, the fewer will be the root-lice in the field in the beginning of the season. By this means a check will also be placed upon the increase of the ants themselves, by the destruction of their helpless maggotlike young which they have brought thru the winter in their nests. Furthermore, the

young weeds in the field on which the root-lice are dependent for food until the corn begins to grow may thus be so thoroly destroyed as to result in the starvation of the insects. Fortunately the labor of this treatment of the field will usually be more than repaid by an improvement of the corn crop independent of all protection against aphid injury, this being practically the preparation for corn especially recommended by our best teachers of high-grade agriculture and practiced by some of our most successful corn farmers.

It should be clearly understood, however, that this measure will not destroy all the root-aphids in the field. In a few cases ants' nests will go so deep that a part of their contents will be undisturbed by the plow, and will thus remain as centers of infestation from which the ants and aphids spread later to reoccupy the field. Furthermore, the corn-field ant, even under these difficult and discouraging conditions, will sometimes search out and bring together again at least a part of the scattered contents of its burrows.

The outcome of several carefully conducted experiments with this cultivation method of preventing the root-louse injury, is given in Bulletin 104 of the Illinois Agricultural Experiment Station, pp. 102-123, and also in the Twenty-fourth Report of the Illinois State Entomologist, pp. 8-29.

3. *The maintenance and increase of the fertility of the soil.* The richer the ground and the more thrifty the crop the less, other things being equal, will be the injury to plants by the root-louse. We have no present evidence that these insects thrive any the less or multiply any less rapidly on the thrifty corn plant than on one poorly nourished, but there is, of course, no doubt that the plant itself suffers most under insect attack when it has least surplus of vigor and sap to spare. In this respect also, the corn root-aphid helps to enforce the teachings of a better agriculture, increasing the penalty of a poor management by still further diminishing the yield of a deteriorating soil.

4. Finally, *the use of repellents on the seed as described in this paper.* This is still an experimental measure, and evidently can not be commonly relied upon until we know more of its general and average results. It seems to me desirable, however, that a considerable plot should be planted each favorable year in each suitable field, with seed treated by one or the other of the odoriferous repellents here discussed, or, still better, perhaps, by one of the strongest-smelling fertilizers, to be applied by means of a fertilizer dropper; and that the consequences of this treatment should be carefully studied by a comparison of the product of this plot with that of adjacent parts of the field. By a favorable year is meant one in which the spring is of a fairly average character—a little drier than normal, perhaps—and in which, consequently, the seed is likely to grow quickly and the plant to get a good and early start. By a suitable field is meant one in corn for a year or more preceding, and in which nests of the corn-field ant are turned out in plowing at the rate of some fifty or sixty to the mile

of furrow. If they are fewer than this it may be that, in a year favorable for corn, no sufficient injury to any of the plants will be done by the root-lice to make any noticeable difference between corn growing from treated and from untreated seed.

As a safeguard against possible injury to the kind of seed one is using by the kind of materials one may chance to purchase, and in view especially of the well-known differences in seed and the differences also in materials of chemical manufacture, each experiment should be preceded by a seed-corn test, made in the usual form but in a way to bring into comparison treated and untreated seed with respect to the percentage of kernels to grow. In this way the possible failure of an experiment and some loss of stand may be prevented.

HABITS AND BEHAVIOR OF THE CORN- FIELD ANT, *LASIUS NIGER* *AMERICANUS*

The little brown ant notorious for its injuries to corn, and called by us, consequently, the corn-field ant, is not by any means limited to corn fields, but is abundant in all cultivated lands, in pastures and meadows, in dense forests, along hard pathways, and in the sandy soil of dry sunny roads. One sometimes finds it nesting in rotten wood or under bark, logs, or stones, and even opening up its underground burrows to the surface between the bricks of sidewalks and pavements. It is distributed "over the whole of North America, except the extreme southern and southwestern portions, from the tree line on the highest mountains to the sands of the shore."* Wheeler says that it is the most abundant of our ants, and hence of all our insects.

Its homes and habits have been chiefly studied in corn fields, and there it forms rather extensive settlements, mainly centered in the hills of corn, several adjacent hills so occupied by it being connected by underground channels by way of which members of the same family may pass from hill to hill. This is partly, no doubt, because in corn fields it is usually in possession of plant-lice which live on the roots of corn and which contribute to the support of the ants the fluid surplus of their own food, but partly also because in the corn hills it is undisturbed by the cultivator, which is likely to tear up its nests if they are established between the rows.

CONTENTS OF THE NESTS

In the burrows of this ant one may find a rather mixed and varied population, consisting of the eggs, larvæ, pupæ, males, females, and workers of the ants themselves, together with the various species of root-lice harbored by them and certain kinds of mites which share its underground habitations on terms of mutual toleration if not of active friendship. In clover fields it is very likely to have in its nests many mealy-bugs (*Pseudococcus trifolii* Forbes) of a species which infests the roots of the clover plant, and these it treats as it does the root-lice of the corn plant, seizing them and carrying them away when its nest is disturbed, just as it hurries out of sight its own maggotlike larvæ, its egglike pupæ, and its minute, spherical white eggs.

The contents of the nest are not precisely the same at all times of the year. In winter, for example, one finds in it no males or pupæ of the ants, as a rule, but only workers and larvæ, companion mites, and the eggs of root-lice. In some of the large winter nests one or more wingless queens or mother ants may be found, altho we have not been

*An Annotated List of the Ants of New Jersey, by Wm. Morton Wheeler. Bull. Am. Mus. Nat. Hist., Vol. I., p. 393.

able to satisfy ourselves that this is true of all, or even of most, of the winter communities of this species. A careful search and exploration of all the tunnels and chambers of large nests have often failed to bring to light a single queen. Sometimes, however, two or more queens may be seen living contentedly in the same worker family, performing their proper function of laying eggs for the increase of the colony. Besides these large composite and evidently well-established communities, one may often find single females in the ground, sometimes wholly alone, and sometimes with a few of their own eggs, a few larvæ, and a small number of workers which are mainly undersized, but with no root-lice in possession and no companion mites. Late in fall these scattered solitary females may have nothing with them in their pocketlike underground cells except a small cluster of their own eggs. These minor groups with a single female in charge, are the beginnings of a new family, and do not often reach more than a score or so of individuals by the end of the first year. The larger compound groups are older families, how old in any given case we have no present means of knowing.

BEGINNING OF A NEW COLONY

Beginning now with a single female, which came out from an established colony as a winged ant but later broke off her own wings, burrowed in the earth, and began to lay eggs for another generation, we will follow the history of the new enterprise thru the first year, so far as our notes and observations enable us to go. Females and males hatching from pupæ as winged ants in the underground nests from June to October, swarm out of their burrows as if by common consent in August or September. Such an occurrence was noticed by Mr. H. Garman, at Urbana, at 5 p. m. September 14, 1885. Males and females came rapidly up from their burrows under ground and, climbing the nearest blades of grass, took flight one by one, in various directions, the workers in the meantime running rapidly about in a state of great excitement. The males perish before winter, and the scattered females go into the ground, each making for herself an oval or spherical cavity, the beginning of a new family home. Some of these buried females begin to lay eggs in summer and fall—August 15 to November 10, as we have seen them—but others live there alone until spring, depositing their first eggs, according to our observations, from the first to the middle of May, and continuing to lay additional eggs, a few at a time, until September. The minute, maggotlike, footless, and helpless larvæ begin to hatch from these eggs in June, and this hatching process may continue until October. The first larvæ to appear are fed by the female from the contents of her own stomach, which, as she is said to take no food during this period, are believed to come from the nutriment stored up in her own body.* We have found

*Charles Janet has lately shown that the muscles of the wings of the female, used only for a few hours during her whole life, break down within her body into a food supply available for the production of her eggs and the nourishment of her young. *Anatomie du Corselet et Histolyse des Muscles Vibrateurs, après le Vol Nuptial chez la Reine de la Fourmi Lasius niger*. Limoges, 1908.

the oldest larvæ full grown and beginning to pupate from the 12th to the 16th of June, and pupation continues, of course, thruout the season, as larvæ from the later eggs successively get their growth. The first workers to emerge from the pupæ in these small colonies come out early in July—from the 7th to the 11th of that month, according to our experience—and the last emerge in October, or possibly in November.

From solitary queens brought in from the field April 26 to May 3, 1906, and kept in the insectary under natural conditions, the first eggs were obtained May 8, 9, 10, and 15, and the first larvæ from these eggs June 4. The length of the egg stage in the various lots deposited by these females varied from twenty-two to twenty-eight days. The larvæ began to pupate about the middle of June, the larval period being, in four cases, sixteen, seventeen, nineteen, and twenty-three days. The first adult appeared in this cage July 7, and others emerged at intervals thruout the remainder of the year, the pupal stage averaging about eighteen days. Judging by these data, the time from the deposit of the egg to the appearance of the adult is approximately two months. In several cases where second egg-masses were laid on dates definitely ascertained, these dates were found to coincide closely with the time of pupation of larvæ from the previous lot of eggs laid by the same female.

The notes of my field observers make no definite statements as to the numbers thus produced during the first season of the queen's independent life, but three families reared under observation in our insectary, in 1906, gave respectively, 8, 9, and 19 workers as the final product of the season's operations. These numbers are perhaps too small for the average in the field, altho larger than those of families reared during the first year by the carpenter-ant, as reported by Pricer in 1907.* Forty-one first-year colonies of this latter species contained from 2 to 27 workers, with an average of 10; and 19 colonies of a related ant (*Camponotus ferrugineus*) contained from 2 to 19 workers, with an average of only 6.

The process of growth and multiplication are interrupted by winter, during which the ants hibernate in a dormant state in whatever stage they happen to have reached, resuming their activities in spring at the point where cold weather arrested them. The workers open up the nests to the surface, usually in late March or in April, the evidence of this beginning of their seasonal activities being the appearance of circular heaps of minute pellets of earth around the mouths of their burrows. The young larvæ grow little, if at all, as long as the weather is cool, but, fed and cared for by the workers, increase rapidly in size as soon as the weather becomes warm, the oldest of them reaching the pupal state as early as May. Whether males and females appear in the family colony during this second summer is not definitely known, but it is rendered very doubtful by the small size of the family during the

*The Life History of the Carpenter-ant, by John Lossen Pricer. Biological Bulletin, February, 1908, pp. 177-218.

first spring and by Pricer's observations concerning the carpenter-ant, from which he concludes that winged males and females do not appear in the colony until it is more than two years old. Some support for this conclusion as applying to our corn-field ant will presently be given. We can not follow the history of the colony farther at this time, lacking detailed knowledge of the rate of its increase and the form of its organization. We only know that family groups enlarge to contain several hundred workers, and larvæ sometimes by the thousand, with pupæ, males, and queens in much smaller numbers.

SIZE OF COLONIES

The following table shows the number of ants of all stages contained in 20 nests dug out in an oats field by Mr. Kelly August 28, 1906. The fact that the larger numbers are all multiples of 10 or 5 shows that these counts are not to be regarded as exact.

ANTS IN TWENTY NESTS, IN OATS FIELD, AUGUST 28, 1906

Workers	Larvæ	Pupæ	Males	Young females	Old queens	Queen pupæ	Total
41	60	16	0	0	1	0	118
75	50	16	0	0	1	0	142
160	400	30	0	0			590
183	435	15	5	17			655
190	530	60	26	4			810
220	430	75	21	3	1	7	757
260	650	210	11	27			1158
280	340	120	12	20			772
330	150	240	6	24			750
340	150	60	0	5			555
360	750	30	13	33			1186
380	420	35	2	19			856
410	700	120	14	21			1265
475	235	115	0	16			841
540	150	250	6	29			975
585	280	125	0	16			1006
680	240	125	31	12			1088
740	310	180	19	15			1264
860	200	160	16	34			1270
900	450	25	21	38			1434

It will be noticed, on examining this table—the figures for which are arranged in the order of the number of workers in each nest—that the first three colonies are of a different class from the remainder, marked by the absence of winged ants of either sex, and by relatively small numbers of worker larvæ and worker pupæ. These numbers are apparently too large, however, for a first-year colony, and are probably the result of two years' multiplication from the sole queen founder. Possibly the third of the series, with its 160 workers, 400 larvæ, and 30 pupæ, is a third-year family. The small number of males and

females in the remaining families as compared with the workers, larvæ, and pupæ, can not be explained without a better knowledge of the economy of this species. It will be noticed that the fully developed nests, that is, those containing ants in the various stages due at this season of the year, vary in number from 655 to 1434, with an average for the 17 larger nests of 979.

It is probable that families reach their largest size in grass-lands, where they may multiply without disturbance year after year; and consistently with this supposition Mr. Kelly found in following the plow in a field of grass in April, 1906, some of the largest nests of our record. In one nest were nearly 6000 larvæ and 300 workers, with no eggs, no pupæ, and no queen. Thirty-nine other nests in this field were seemingly as large as this.

INTERCOLONIAL HOSTILITIES

The well-known but remarkable hostility of ants of one colony to those of another of their own species is well illustrated by many of the observations of my field and laboratory assistants.

For example, the first of April, 1906, a strange queen introduced to a group of some forty workers of the corn-field ant confined in a formicary, was ruthlessly attacked and killed by them as an intruder. Precisely the same observation was made in another case April 27.

August 15, 1905, a wandering lone queen placed in a formicary inclosure with five males from another locality killed two of them the same day. During the following night two stray worker ants of her species entered the formicary thru a crevice and attacked the queen, one of them seizing her foot with its mandibles and holding fast for an hour and a half. when, as it could not be compelled to release the queen, it was killed to save her.

August 16, 1905, a strange male was first placed among twenty workers in a formicary, but being instantly attacked it was transferred to another containing only a lone queen—one who having rid herself of her wings was presumably already fertilized. The male being dead in the morning, the presumption is strong that the queen killed it. In another case, occurring August 15, four males placed in the nest with a strange queen were immediately attacked by her, and two of them were presently killed. On the other hand, a queen ant still bearing her wings, placed alone with a strange male August 21, made friends with him immediately. The two continued to live in harmony, the queen sometimes caressing the male and even apparently feeding him, until the 26th, when she began to try to pull off her wings and refused to have anything further to do with the male. September 6, altho still bearing her wings, having failed in her efforts to remove them, she began to lay eggs. This seems a possible case of fertilization of the queen within the formicary, but direct observations to that effect are wanting.

August 16, a male from one formicary put in with the workers of another was immediately pounced upon by them, and would evidently have been killed if he had not been promptly rescued.

August 15, worker ants taken from two different nests in the field and placed in the same formicary began at once to fight. They kept up their contest all night, and several of them were dead in the morning. By noon of the following day, however, fighting had ceased and the two groups had separated, occupying different parts of the enclosure. The larger group had taken possession of a corn plant which had been introduced for the use of these ants, and the other colony, which established itself near the edge of the formicary, seemed timid and cowed, apparently fearing even to feed upon the syrup offered them. The dominant group mined actively in the earth about the roots of the corn, and appropriated the root-lice introduced into the cage, evidently feeling themselves masters of their domain.

April 24, 1906, a colony of 100 worker ants with 200 larvæ of various sizes, and eggs of the corn root-aphis, were brought in from the field and established in a two-celled glass formicary. After they had become thoroly at home, nine worker ants and a few ant larvæ—strangers to the original colony—a bunch of aphis eggs, and some young root-aphids, were introduced into this nest, the original family being in the orange or dark cell and the newcomers in the other cell of this cage. As soon as the presence of the strangers was detected they were attacked by the old colony, which dragged the adults about, killing them one by one, ate up their larvæ, ate or pulled to pieces the root-lice introduced with them, and crushed the aphis eggs. The root-lice and eggs brought in from their own nest they were in the meantime caring for as usual.

August 7, some eggs of the corn-field ant brought in from the field and placed with a colony of workers well established in an artificial formicary, were presently found by one of the workers and deliberately crushed, one by one.

These hostilities of ants to strangers may extend even to those of their own sisterhood who have been away from home too long. For example, a young worker separated from its formicary mates August 21, kept alone, and returned to them twenty-one days later, was immediately attacked by them and quickly killed.

The utility to the ants of this inhospitable savagery—this spirit of ferocious clannishness—is doubtless to be found in their social organization, and in the necessity under which they live of keeping always an active, compact, deeply interested group of workers completely devoted to the care and nurture of their helpless young. No young of any animal can be more utterly dependent than those of these ants, and their feeding and protection must be the constant, consuming care of the whole family group.

The workers are, on the other hand, among the most active and enterprising wanderers and foragers among insects, traveling far and wide on foot to distances which make it necessary for them to retrace their steps carefully, whether by the aid of the sense of sight or by antennal senses supposed to resemble what in us is the sense of smell. The homing instinct and the nursing instinct are in them so strong as

practically to rule their lives. They go abroad in search of food for the family, and to the family they must return, however far they may travel and into whatever difficulties and adventures they may fall by the way.

These facts make it necessary that there should be in the economy of ant society some self-acting, self-regulating apparatus for keeping the family groups wholly separate and distinct, for making sure that every foraging worker shall find its way back to its own companions—that it shall neither be liable to lose its way completely nor likely to attach itself to an alien family. From this point of view it is greatly to the general interest that it should find a welcome and a permanent home only among its immediate kindred and habitual companions, and nothing could make this condition more secure than a universally hostile reception to the wanderer in every other family group. Clan-nishness in ants has thus the same justification that it has among savage men. It is a means of maintaining the necessary concentration of the group for the care of the young, and hence for the preservation of the race.

AREA OCCUPIED BY A SINGLE COLONY

Practical advantage was taken by us of this intolerance of ants towards those of other parentage to ascertain the limits in the corn-field of a single colony or family group. Assuming that specimens from adjacent hills of corn are members of the same family if they affiliate peaceably, but that they belong to different families if they fight, I instructed my field assistant to bring the inhabitants of adjacent hills into contact with each other in artificial nests until all those affiliating with the original group used as a test were distinguished from those about them who refused peaceable affiliation. By a careful application of this method at Elliott, May 23, 1906, two family areas were thus marked out.

The group of hills included in the first experiment occupied an area 10 hills in length by 7 in width, and 20 of these 70 hills were infested by ants. Selecting the inhabitants of a hill from the center of this tract for the purposes of this test, ants from the other infested hills were placed with them successively. By this means it was found that the inhabitants of ten of these hills were members of one community, harmonizing with each other perfectly when commingled, but that those of the other nine were strangers to them, since the representatives of these groups instantly fought when placed together. The ten nests thus identified as related were distributed over an irregular area about 30 feet long by 14 feet in greatest width, and were probably all connected by a network of underground channels. Hills inhabited by hostile ants were in many cases immediately next to others occupied by members of this family group.

The second experiment covered a plot of 130 hills, 32 of which were occupied by the corn-field ant. The occupants of 12 of these hills affiliated peaceably, while the remaining 20 were rejected by the

original colony used in making the test. The family settlement thus outlined, also irregular in shape, was about 30 feet long by 10 feet in greatest breadth. There was no intermingling of hostile groups in either of these family areas, all the ants occupying hills within the boundaries of each being on friendly terms.

RELATIONS TO OTHER SPECIES OF ANTS

Notwithstanding the almost invariable intolerance exhibited by different families of the corn-field ant towards each other, they sometimes live on perfectly friendly terms with ants of other species, both kinds mingling harmoniously in the same galleries among the roots of the same hills of corn. One of the small red house-ants (*Solenopsis molesta*) which often infests kitchens and pantries to the annoyance of the housekeeper, is frequently found at home in the nests of our corn-field species. A mixed settlement of these two ants found in a field near Urbana August 31, 1905, and brought to the insectary and established in a jar of earth, collected their larvæ and pupæ into separate lots without contention, and continued for several days to feed peaceably together from the same food supply. August 29 another species common in corn fields, *Formica schaufussi*, was found by Mr. Kelly inhabiting the nests of *Lasius niger americanus*, the larvæ and pupæ of both being, as he says, mingled in the same heap. Transferred to a Mason fruit-jar and brought to the insectary, they lived together for two days in a Lubbock nest without fighting; but afterwards hostilities broke out and all the *Formicas* were killed save two which remained in hiding, and their pupæ were thrown by their conquerors into the ditch surrounding the nest.

BEHAVIOR WITHIN THE NEST

From a colony of ants obtained August 15 and established in a Fielde nest, one of seven queens was removed and placed by herself August 16 in a glass Petrie dish with moist earth, for special observation. She had broken off her wings the previous day, and was hence presumably fertilized, altho she apparently had not left her native nest. She began at once working in the earth as if to make a burrow. This is the queen which killed a male placed with her, as described on another page. She worked restlessly in the earth for several days, helping herself to the sugar syrup offered her, and deposited six eggs August 25. It is commonly supposed that a fertile queen does not feed after leaving the family nest until she has reared workers capable of supplying her with food. Possibly her nest was kept too dry and the syrup was taken as drink rather than as food.

Another queen brought in from the field August 15, pulled off three of her wings within the next two days, but did not succeed in ridding herself of the fourth until August 25. This queen was reported by Mr. Kelly to partake once or twice a day of the syrup placed in her cell. She busied herself with piling up the dirt beside a bit of wet sponge, sometimes undoing at one time what she had done at another. She laid no eggs, and died September 6.

The significance of males in the ordinary life of the colony is very small, and I have but few notes on their habits and behavior. July 31 a worker, a male, and a pupa were placed together in a Petrie dish, the pupa almost mature. This is a situation of great responsibility for the worker ants, whose aid is necessary to the successful emergence of the adult, and the single worker upon whom these labors fell made every effort to discharge her duties alone, the male doing nothing in her aid. The anxious and affectionate worker divided her attentions between the helpless pupa and this idle male, caressing and feeding him, and when, thru a misadventure, his wings were stuck to the cover of the cell in the moisture which collected there, doing her best to pull him loose. When the pupa was ready to yield the adult the end of the pupa-case was bitten off by the worker ant; and its inmate pulled out head first in a helpless condition, unable even to stand. In about three hours, however, it was walking about.

When the workers were moving the family from one cell of the formicary to another, they were often seen dragging the males along to the new quarters, as if ants of this stupid sex were unable to get any idea of what was going on, and must be dealt with by physical force.

The responsibility of the workers for the successful transformation of the pupa and the appearance of the adult is well illustrated by an observation recorded by Mr. Kelly under date of August 17. In a glass Petrie dish in which three workers and three pupæ of the corn-field ant had been placed for observation August 2, a worker emerged from a pupa-case, two of the workers in the cell assisting. One of these bit off the black tip of the pupa-case and slowly pulled the young ant out, taking three minutes for the operation. The head of the newborn worker was cleaned off and its antennæ were straightened out by the mouth-parts of one of its nurses, while the other loosened and straightened its legs. At the end of sixteen minutes from its release it made its first attempts to walk. In this, as in other cases observed, the workers rewarded themselves by devouring the empty pupa-case.

The constant attention which the worker ants pay to their eggs and larvæ is so well known that it scarcely requires illustration. Many of their ministrations, it is true, seem aimless and mechanical, mere restless movements of their charges from place to place, but the constant attention given by the workers to their young is an effective safeguard against any ordinary injury.

The eggs, deposited by the female, are gathered together by the workers, kept in a pile or ball convenient of transportation in a mass, and carried up and down in the nest according to the weather; and as they hatch the young are separated from the mass of eggs and kept by themselves, usually assorted according to size as they increase in number and differ in age. Larvæ and pupæ are likewise commonly kept distinct, the various lots doubtless requiring somewhat different care.

The workers feed their larvæ almost constantly from the contents of their own stomachs, and often mouth and hover them, a mass of

the ants clustering around and over them in a way to conceal them from view. When the colony is established in a two-celled nest, one covered with clear glass and the other with orange, the workers convey their young to the orange cell, the light transmitted by orange glass being, as shown by Miss Fielde, inappreciable by ants.

Even after the workers have emerged from the pupa-case they are still watched and cared for by their more experienced relatives, and often fed in the nest by foragers returning from outside. This operation was illustrated in our breeding-cages when pale young workers remaining within the orange cell were fed by the darker, older ones from food exposed to them in the light cell of the formicary.

The nursing instinct of the workers is so overruling that it extends to all the inmates of the nest excepting only strangers of their own species. A common resident of the nest of these ants is a species of mite (*Macrocheles mastus* Banks) often found crawling about among the eggs and larvæ, altho never detected in any depredation upon them. It is probably a scavenger of the domicil, and is thus possibly entitled to the protection which it receives. When a nest containing these mites is disturbed, they receive the same attention as its other inmates from the alarmed and anxious workers. In several nests for example, plowed up April 24, in an old oats field, mites were commonly present, and the ants seized them in their mandibles and carried them away as they did their own young.

ADAPTATION OF BEHAVIOR TO CHANGING CONDITIONS

The movements of ants in their outdoor habitations often show a surprising adaptation of habit and behavior to changing conditions in the field. It was repeatedly noticed, for example, that during warm dry weather in early spring the aphid eggs would often be brought near the surface while the larvæ of the ants were kept at a depth of five or six inches below. The effect of this treatment must be to hasten the hatching of the aphids and at the same time to retard the development of the larvæ of the ants. The growth of the latter is thus kept practically at a standstill while food is scarce in spring, but proceeds at a rapid pace after the aphids have hatched and are yielding an abundant food supply to the colony. In periods of summer drouth the burrows are extended downward to a depth of twelve or fifteen inches, and eggs, larvæ, and pupæ are carried down into relatively moist earth. The ants then mass up in the depths of their burrows and are rarely seen abroad, but communicate with their root-louse herds by means of underground passageways, sometimes several feet in length. When soaking rains come, these hidden colonies open up their burrows to the surface again, as the ground dries off, and resume their more active habits as general foragers.

Under certain conditions of serious deprivation and suffering, however, this whole system breaks down, and the ants may devour, for their own temporary maintenance, the very objects to which they have previously devoted their entire existence. When infested plants wither

and die, and no others can be found to which the aphids may be transferred, these are themselves eaten by the workers as a food material too valuable to waste. When suffering from a lack of sufficient animal food, the workers in our formicaries have occasionally helped themselves to a living pupa of their own species, or have even devoured the larvæ in their charge, to the last one. The corn-field ant is, in fact, essentially a carnivorous insect, and forages actively for animal food, especially when it is without a sufficient number of root-lice. Much of our breeding-cage work came to naught thru the mysterious death of the workers, apparently because their liking for a watery syrup was regarded as evidence that this was a sufficient food for them. In the field and in the insectary we have seen ants feed at various times and under various conditions upon cutworms, carabid larvæ, white-grubs, dead May-beetles, dead beetles of the corn root-worm, dead grasshoppers, root-lice, myriapods, earthworms, their own pupæ and larvæ, and the pupal envelopes vacated by adults on transformation. Occasionally they have been seen injuring corn by hollowing out the soft seed either before or after sprouting, and in one case at least they were reported by an insectary assistant as feeding on the fibrous roots of the plant.

AN INJURY TO CORN BY ANTS

Under certain conditions, indeed, this corn-field ant may do considerable injury to corn by a direct, unaided attack. During the cool, wet spring of 1905, when the softened kernels lay long in the earth without sprouting, and the young plants grew very slowly for a time, a field of corn following oats, heavily infested by ants which had no root-lice in their possession, was considerably damaged by the ants, which gnawed and hollowed out the seed, thus either killing it, or so diminishing the food reserve that the plant made a slow and feeble start.

This field of forty acres, lying near Champaign, had been in oats in 1904, in corn in 1903, and in grass in 1902. The corn was said by the tenant to have been injured by root-lice in 1903, the part worst infested yielding not over 22 bushels to the acre, while the remainder of the field gave a yield of 55 to 60 bushels. Owing to a report that the young corn was being injured by ants, Dr. J. W. Folsom, of the University department of instruction, examined it for me May 31, digging up sixty-one hills in a way to expose the whole root system. Forty-one of these hills were in a part of the field but moderately infested with ants, and thirteen were in an adjacent part in which ants were very abundant. In both cases the hills examined were taken as they came, one after the other in the row. Seven hills additional were dug up here and there, because of an especially noticeable infestation. The corn in this field was unequal in condition, the poorer hills being most numerous where ants were most abundant. This unthrifty corn was four or five inches high, and of a yellowish hue, while the better plants were six or seven inches high, and of a good green color.

In the less-infested row six hills out of forty-one were infested by the corn-field ant, one of them containing also the red house-ant

(*Solenopsis debilis*). In five of the six infested hills a single kernel of corn had been more or less eaten by the ants. No observations of injury to the roots were reported, but the amount of stunted corn in this part of the field could scarcely be accounted for except on the supposition that some other injury was being done than this to the kernel in the hill. In the worse-infested part of the field thirteen hills were examined, eleven of which were infested, and eight of them contained kernels which had been more or less eaten by the ants. In five of the hills all the kernels had been thus injured, and in the others only one kernel to the hill. The ants in these hills were all the common corn-field species except in one instance, where only *Solenopsis* was found. In the seven hills selected because of their visible infestation, all the kernels were eaten by ants in two, and a single kernel out of two or three in each of the others, the ants in all these hills being the common corn-field species. Rough estimates of the number of ants to a hill ranged from ten workers as a minimum to a maximum of a thousand. In one case only were ant larvæ present.

In all these sixty-one hills the corn root-aphis was found but four times—twice a single winged female, once a winged female with three large and thirty small wingless females, and once four winged females with between forty and fifty wingless ones, nearly all of them young. There were, in fact, more of the common grass root-louse (*Schizoneura panicola*) in the field than of the corn root-aphis, some on the roots of corn, with ants in charge, and others on smartweed and ragweed roots, and also accompanied by ants.

From these observations we may infer that ants living in the meadow-grass in 1902 with grass root-lice in their possession, infested the corn the following year; that they continued in the field through 1904, when a crop of oats was raised, carrying a small percentage of their grass root-lice over on roots of weeds in the field; and that when the ground was planted to corn in 1905 they were still abundant there, but with so few root-lice in their possession that they availed themselves of the softened corn kernels in the earth for food, probably gnawing away, also, root hairs and the finer roots, as they have been seen to do in confinement.

EFFECT OF A CHANGE OF CROP

The effect of a change of crop—from corn to oats, for example—on the ant population of a badly infested field, was illustrated by an account in my Thirteenth Report of the disappearance, during the latter part of May, of both ants and aphids from an oats field formerly in corn. By this time the weeds in the field were practically all dead, the oats having reached a height to overshadow and sap them. A similar occurrence, more closely observed, is reported by Mr. Kelly in a series of notes running from April 21 to June 22, 1906. In a forty-acre field of oats fifty nests of the corn-field ant were located and marked near two sides of the field, one next a field of corn and the other separated from corn by a hedge fence and a road. That this

field had been heavily infested by root-lice the preceding year was shown by the number of aphis eggs and young aphids in possession of the ants—the aphids on roots of smartweed and grasslike weeds in the field. The ants themselves lived mainly under ground, at least by day, rarely opening their burrows to the surface, until the 4th of May, when, as the weather warmed up after a heavy rain, they made their presence known by a deposit of pellets of earth at the surface around the openings of their burrows. The oats at this time were about four inches high, and smartweeds and ragweeds about half as tall. Both the latter had many root-lice on them, but none were on the roots of the oats, and the aphis eggs were not yet all hatched. Nests of the ants were very abundant in the grass outside the borders of the field, and several of these which were opened up contained corn root-aphids on the roots of the grass. From the 8th to the 10th of May the ants were actively running over the ground as if in search of food, but, so far as could be seen, with meager result. The second generation of aphids had by this time begun to appear, and many of the smartweeds were dead at the root. The ground was very dry for the next few days, and both grain and weeds grew very slowly, many of the oat plants being dead. Thus matters went on, with no material change except that the ants were found feeding freely on dead June-beetles and other insects, until June 5, when it was noticed that the ants were leaving the field.

“As I was returning home last evening,” says Mr. Kelly, “I noticed crossing the lane beside this field a colony of *Lasius niger americanus*, composed of ants going in both directions between the field of oats and the corn field on the opposite side of the road. I followed the column thru a hedge fence and about twenty feet into the oats, where they were coming out of their nest. Some of those going outward were carrying larvæ, but none of those returning in the other direction. The line of march was indirect, and about fifty-seven feet long, ending in the grass on the opposite side of the road, where a new nest was being formed. The colony was still moving at 6 the following morning, evidently having been at work all night. They had finished the transfer before 8 a. m., nothing remaining in the nest from which they had emerged. No root-lice were in their possession, but only their own larvæ.”

Finally, on the 22d of June, a thoro search was made of the sites of all the nests marked as originally occupied by ants. Forty-nine of the fifty were identified, the remaining one being lost. Forty-four of these nests had been completely deserted, and only five were still inhabited by ants. These were in rather open spots in the field, with an abundance of grass about them. There were no corn root-lice on this grass, however, but only the grass root-louse (*Schizoneura panicola*) and a few *Geioica squamosa*. The oats at this time reached about to the knee, and were beginning to head.

From these data, combined with those previously published, we may infer a gradual but general migration of the ants from the old

corn field, now in oats, to more favorable locations,—a migration which included all the ants, of whatever age or condition, but in which their aphid possessions were apparently sacrificed—probably eaten by their owners as a last resort of domestic economy. Not all the aphids of the oats field were thus lost, however, but some seem to have been transplanted to grasses near by, and others, which acquired wings as food began to fail, escaped by flight. Such winged aphids were repeatedly seen to be captured by wandering ants, who took them in charge and placed them on the roots of suitable plants. Others, lighting by chance on a corn plant, made their own way down the stalk, and thus found a lodgment on the roots, where they were doubtless afterwards found and cared for by ants. Nevertheless, the loss of rootlice consequent upon a change of crop, altho not complete, must have been enormous, only now and then one of the aphid inhabitants of the field being fortunate enough to fall upon favorable conditions; and crop rotation remains one of the most effective means of checking the multiplication of these destructive insects.

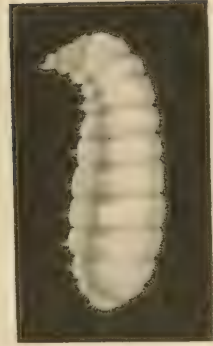


PLATE I.

STAGES OF THE CORN-FIELD ANT (*Lasius niger americanus*): worker; larva; winged male; pupa; winged female; female with wings removed.

THE INSECT PESTS OF CLOVER AND ALFALFA

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INTRODUCTION

This account contains a large amount of new information on the most injurious of the clover insects, and on some of the less important species as well. Unless otherwise indicated, the observations were made by the writer during three summers in which he was employed by the State Entomologist, Dr. Stephen A. Forbes, for the special purpose of studying these important insects.

The volume of the results obtained—many of them as yet unpublished—is due in no small measure to the help of an assistant, especially in the routine work of the insectary; and in this capacity there have served at one time or another, Messrs. E. V. Bronson, E. O. G. Kelly, R. L. Webster, and J. J. Davis. Their names appear later wherever their personal observations have been used.

The present account contains not only new material, but also everything of importance that has previously appeared in our literature of the subject. The literature is large, but the greater part of it is a mass of more or less useful repetition, which traces back to a few sources. All the original articles are cited in the lists of references, as are also the more useful of the compiled articles. These references, tho not voluminous, are comprehensive, and sufficient to guide one directly to all the authentic sources of information on each subject treated.

Most of the illustrations were drawn for the State Entomologist by Miss Charlotte M. Pinkerton, Mr. F. Knab, and Mr. W. C. Matthews. Several electrotypes were obtained from the Bureau of Entomology thru the courtesy of the Chief, Dr. L. O. Howard.

In the account that follows, consideration is given primarily to the insect pests of red clover, and secondarily to those of mammoth clover, white clover, alsike, and alfalfa. The last-named plant, introduced into Illinois some ten years ago, is cultivated here and there in almost every county, and has been adopted as a food plant by a large number of the red-clover insects; but none of them have as yet injured it conspicuously, so far as the writer has been able to learn.

INJURY TO CLOVER BY INSECTS

A field of red clover in full bloom is alive with insects. Such a profusion of insect visitants, both as regards number of individuals and number of species at one and the same time, is afforded by no other plant that we know of, with the possible exception of alfalfa. In the

clover fields of the university farm we have taken two hundred species of insects—not all of them injurious, tho more than half of them feed on the plant. Adding to these the other species that have been listed as feeding on clovers, vetches, and alfalfa, it is seen that these plants are food for more than two hundred different kinds of insects. A hundred more are predaceous or parasitic on these clover insects, or else feed on animal or vegetable matter in the soil of the clover field.

No part of the plant escapes attack. The roots are eaten by the larvæ and the beetles of the root-borer, as well as by those of half a dozen other species, and are drained of their sap by the mealy bug. The stem is hollowed out by the common stem-borer. Both the stems and the leaves are pierced by many hemipterous insects, especially aphids and jassids, and are eaten by a great variety of caterpillars, beetles, and grasshoppers, as are also the heads of the flowers. The ovule is destroyed by the maggot of the seed-midge, and the developing seed is eaten out by the seed-chalcid. Even clover hay is the special food of a certain caterpillar, hence called the clover hay-worm.

Some of the insects of the clover field are, of course, beneficial. Such are those that pollinize the flowers,—bumblebees and, to some extent, honey-bees,—as well as those that act as checks on the injurious insects.

Most of the clover insects are not limited to clover, but have other food plants as well. The seed-midge and the seed-caterpillar are, however, confined to the clovers, and the seed-chalcid to clovers and alfalfa, so far as known. The root-borer is said to eat peas as well as clover. The hay-worm has been found only on hay as yet, but the moth has been raised from masses of dead grape leaves taken in a vineyard. The leaf-weevil is reported from beans and timothy, as well as clover and alfalfa. The clover-louse has been a pest of the worst kind on peas and has a long list of food plants. Of the less important clover insects, a few have no other food plant; but the majority can easily maintain their existence when no clover is at hand.

In Illinois, where alfalfa is a recent introduction, its insects are essentially the same as those of red clover, and it has as yet no insects peculiar to itself. The leaf-weevil, seed-chalcid, and root-borer feed on alfalfa, but not enough to have done any damage up to the present time. Even the numerous caterpillars, beetles, and grasshoppers that eat the foliage have not yet injured this newly introduced plant to any great extent. An insect that eats a few alfalfa leaves is not necessarily inflicting permanent injury upon the plant; for, up to a certain point, the plant is injured by leaf-eating insects no more than a fruit tree is injured by pruning. Red clover, also, is such a vigorous plant that it easily withstands or repairs injuries of an ordinary kind. Thus in April, 1907, 25 to 50 percent of the new leaves of red clover were frozen and killed in this region, but the hay crop was as good as ever. The temporary damage was far greater than that ordinarily inflicted by the miscellaneous clover insects—leaving out of consideration the seven pests named in the previous paragraph.

The combined efforts of all the insects, however, are sufficient to reduce the hay crop materially every year. Aside from the occasional conspicuous injury, there is every year a steady drain on the plant thru the attacks of insects. This annual drain is not noticed for the very reason that it occurs every year. If we could keep all the insects out of the clover field, we should get more hay. If we could exclude all except the bumblebees and the honey-bees, we should undoubtedly get an immense increase in the yield of seed.

Those who raise clover seed on a commercial scale owe their success to methods which operate chiefly against the insect enemies of the seed—whether the growers are aware of it or not. Under the same conditions of soil and climate, one man is able to get a good crop of seed and his neighbor is not. The reasons for this are chiefly entomological, as appears in these pages.

THE FAILURE OF THE SEED CROP

Many farmers do not attempt to raise their own clover seed. Those who do, get more or less of a crop according to circumstances. Here in the black soil of the corn belt, $1\frac{1}{2}$ bushels of seed per acre is about the average yield for red clover (*Trifolium pratense*); the soil is not the best possible for clover; frequently too little seed is sown; generally the oats and the wheat are regarded as of more importance than the clover; and always the seed insects ravage the crop unless certain precautions are taken. In DeKalb county the soil is better adapted to clover, and, tho the winter conditions are now and then a little severe for the plant, the farmer expects to get about five bushels of seed to the acre by cutting the hay crop early. Under the most favorable conditions, red clover has yielded eight bushels per acre; I have found records of nine, but the more authentic accounts name no more than eight.

Many influences, more or less important, combine to reduce the crop of seed. Adverse mechanical or chemical conditions of the soil, or unfavorable conditions of the weather, may prevent the plant from flowering properly. With good conditions of soil and weather, the general health of the plant may be impaired by fungous diseases of several kinds or by insects, particularly the root-borer, the leaf-weevil, and the clover-louse; their devastations cause the heads to flower unevenly and imperfectly, and prevent the formation of a large number of heads in the crop directly attacked by them.

These injuries, due to influences that affect primarily the general health of the plant and secondarily the seed, are easily referable to their respective causes. The worst injuries to the seed are more insidious in their nature, and are caused by insects. These injuries are of three classes: (1) those of a negative kind, due to lack of pollination; (2) the positive injuries due to miscellaneous insects that eat clover heads in an incidental way; (3) the positive injuries caused by insects that feed solely upon clover seeds or florets. The first two groups are relatively unimportant in comparison with the last.

1. We should have no red clover seed at all were it not for the operations of the bumblebees and, secondarily, of the longer-tongued honey-bees (those of Italian races), for red clover is incapable of self-pollination. The importance of the bumblebee in the pollination of red clover is so well established as to need no discussion. That of the honey-bee, however, is not sufficiently recognized. The honey-bee pollinizes red clover to some extent, even tho its tongue is two millimeters shorter than the average corolla tube. A field of red clover is always thronged with honey-bees if any of them are being kept within a mile or two of the place; and these bees secure nectar from flowers that are undersized, especially in times of drought, when most of the flowers are smaller than usual; also from flowers that secrete a copious amount of nectar. Furthermore, the honey-bees, in their attempts to get the nectar, go thru the motions of pollination whether they get any nectar or not, as I have ascertained.

The lack of seed in the June or early July crop is generally attributed to the lack of bumblebees at that time, and rightly so, in my opinion. Occasionally, however, the farmer is surprised to find a paying amount of seed in his first crop. This happened in Illinois in 1906 and again in 1907 in various counties in all parts of the state, as I have learned from correspondence and from personal conversation with clover growers at the State Farmers' Institute and elsewhere. This early seed ran one to two bushels to the acre; some of it was put on the market in Quincy, Ill. Only two farmers offered any explanation for the production of clover seed at this untimely season, and they laid it to a "miller" that pollenized the flowers by night unobserved. This miller I am not acquainted with; perhaps the honey-bees pollenized the flowers.

Ordinarily, however, we do not expect to get seed from the June crop; and by midsummer there are always enough bees to pollenize the flowers. The failure of the seed crop need not be laid to lack of pollination as yet. In the future, if bumblebees are constantly destroyed we may be obliged to cultivate them artificially—and this can be done, if necessary for the welfare of clover. The indiscriminate killing of bumblebees should be stopped. They are the best friends of the clover grower.

2. The seed crop is diminished to some extent by various grasshoppers, beetles, and caterpillars that eat the blossoms here and there, and sometimes the green seeds. They prevent pollination and destroy developing seeds in some measure, but can scarcely be guarded against, and need no special consideration.

3. There are, however, three insects that must be guarded against if one wishes to raise a good crop of seed. These are the seed-midge, the seed-chalcid, and the seed-caterpillar. When clover blooms well, and there is good weather, the failure of the seed crop is to be charged to these three insects, the last of them being the least to blame, as a rule. All three can be controlled by simple methods described later, the most important of these being the early cutting of the hay crop.

It seems curious at first sight that an unusually large yield of seed should follow the ravages of the clover leaf-weevil. Yet this has occurred in several instances. Webster observed the fact in Ohio. The explanation is simple, however, in my opinion, for the weevil, when a pest, consumes enough leaf tissue to delay the growth of the plant materially, taking the seed crop out of the reach of its worst insect enemies. The result is the same as that obtained by the seed growers who pasture the clover in May or early June.

Early pasturing or cutting is the secret of a good seed crop, as the growers in New York, Ohio, Michigan, Canada, and elsewhere have found. The reason for the practice is not universally known, however, as is evident from the inadequate explanations that have appeared now and then in agricultural publications. For example, Shaw says (*Clovers*, etc., p. 103), "Experience has shown, further, that, as a rule, better crops of clover seed may be obtained from clover that has been pastured off than from that which has been mown for hay, although to this rule there are some exceptions. This arises, in part, from the fact that the energies of the plant have been less drawn upon in producing growth, and, therefore, can produce superior seed heads and seed, and in part from the further fact that there is usually more moisture in the soil at the season when the plants which have been pastured off are growing. There would seem to be some relation between the growing of good crops of clover seed and pasturing the same with sheep." The fact is that pasturing gives a good seed crop for the reason that it delays the heading of the plant until a time when the seed-midges and seed-chalcids are no longer on the wing and laying eggs. When precautions are not taken against these pests, they can be counted upon every year to destroy most of the clover seed. In this region the midge and the chalcid eat from 50 to 75 percent of the red-clover seed every year without hindrance. The farmer gets only what the insects leave. If he gets two bushels of seed to the acre, the insects have already eaten from two to six bushels off the same acre.

CONTROL OF CLOVER INSECTS

The insect pests of clovers are but seven, and they are within our control if we choose to control them. Moreover, they can be controlled by means that interfere little, if any, with usual farm practice; and the methods of control do not conflict with one another, but are essentially the same for all the clover pests,—referring especially to those of red clover.

The worst of these to deal with, where it occurs injuriously, is the root-borer. If it is very destructive in spring, plow the clover under, for this insect has quite its own way. The other pests can be disposed of without sacrificing the plant.

If the hay crop is threatened seriously in spring by the leaf-weevil or the clover-louse, pasture it or clip it back in May; otherwise, cut the hay as early as possible, in order to insure a good second growth. Usually, however, these two insects are subdued by natural agencies, in spite of their abundance.

To get rid of the worst of the seed insects, pasture or clip back in May or early June; or else cut the hay as soon as possible—as soon as it is fresh in bloom, or earlier.

Cut red clover, or pasture it lightly, in the latter part of the first season, as this goes far to reduce the number of insect pests in the same field the second year, and does not injure the clover if done intelligently. Destroy volunteer clover, which is a rich nursery for all kinds of clover insects. It can be cut most conveniently with the rest of the clover—twice a year.

Do not permit red clover to run for more than two years in this region, where it is, for agricultural purposes, a biennial.

CLOVER SEED-MIDGE

Dasyneura leguminicola Lint.

(*Cecidomyia leguminicola*)

This widely distributed pest, abundant in clover fields, prevents the formation of seed. At the time of blossoming, the florets affected by this insect remain for the most part green and undeveloped, and their ovaries are hollowed out and empty, or else contain each a small orange, pink, or whitish maggot. Having entered the flower-bud, the maggot consumes the fluid contents of the ovary before the bud has a chance to open. Hence the term *bud-midge* would be even more appropriate for this insect than that of *flower-midge*—recently proposed by Webster.

The maggots develop into delicate little red-bodied flies, which are so small as easily to escape observation, altho they are very abundant in clover fields at certain periods of the year.

Distribution.—The clover seed-midge has been reported as destructive in Vermont, New York, New Jersey, Pennsylvania, Delaware, the District of Columbia, Virginia, Ohio, Illinois, Iowa, Michigan, Wisconsin, and Nebraska, and doubtless occurs in other states in which clovers are grown. It does great damage in the province of Ontario, Canada, and, according to Miss Ormerod, is also found in England. In Illinois, the pest was observed as long ago as 1878 or 1879 (Fifteenth Rep. State Ent. Ill., p. 3).

Food Plants.—The chief food plant of the species is red clover, but white clover also is affected. The published statement that alsike clover is exempt from attack is incorrect, the writer having reared the midge from alsike. This clover is not badly infested, however, probably because it forms its heads three weeks later than red clover, at a time when there are but few seed-midges on the wing. For the same reason mammoth clover ought to escape severe attack, and such is said by one writer to be the case (*Insect Life*, Vol. V., p. 74). An implication to the contrary, however, is found in another publication (Bull. 116, Mich. Agr. Exper. Station, p. 55). I have had no personal experience with the midge on mammoth clover, but would point out the pos-

sibility that the injury in Michigan was done by the seed-chalcid rather than by the seed-midge.

Alfalfa is not yet known to be a food plant of this insect.

Descriptions.—The egg is barely visible to the naked eye. It is elliptico-cylindrical in form, at most 0.3 mm. long and 0.075 mm. broad, with the shell smooth and transparent. The color is at first a uniform watery yellow, but soon an internal orange spot appears, and finally the egg becomes orange thruout.

The larva (Pl. II., Fig. 1) is a footless maggot, orange-red, pink, or almost white, 2.3 mm. long and one third as broad, when full grown, with the surface of the skin minutely granulate. It has thirteen segments behind the head, and, like other cecidomyiid larvæ, bears nine pairs of respiratory tubercles, situated respectively on segment 2 and segments 5 to 12 inclusive. All these tubercles are lateral in position excepting the first and the last pairs, which are dorsal and posterior on their respective segments. A peculiar organ known as the *sternal spatula* may be detected lying against the ventral face of segment 2, and the form of this organ (Pl. II., Fig. 2), while subject to some variation, is sufficiently characteristic to distinguish this larva from that of the clover leaf-midge, the only other insect with which it is likely to be confused.

The cocoon, made by the larva, is oval in form, 2 mm. long, and composed of silken threads. It is difficult to find out-of-doors owing to its being covered with particles of dirt. The pupa, described in some detail by Comstock, is pale orange, with brown eyes, a pair of short conical tubercles on the front of the head, and a rather long horn near the base of each wing; the antennal sheaths of the cast pupal skin curve outward like the handles of an urn.

The appearance of the female midge is well shown in Figure 3, Plate II. When on the wing, she is nothing but a filmy speck, that easily eludes the vision. After alighting, her red abdomen and long threadlike legs catch the eye. Under the microscope, the head is seen to be black, and the antennæ yellowish red, with sixteen—or even seventeen—sessile segments. The sides of the thorax are reddish brown; above, most of the thorax is black, but two small posterior lobes are brownish red; the halteres are reddish yellow. The wings are transparent, closely set with short, curved, dusky hairs, and strongly fringed posteriorly with long paler hairs. Legs slender, reddish brown, the segments becoming darker distally. The abdominal segments 1 to 6 are salmon-red above, mixed with yellowish beneath; dorsally each of these segments is banded with black scalelike hairs, which rub off easily. Segments 7 to 10 of the abdomen form the pale yellow ovipositor. The insect, with ovipositor retracted, is 1.8 to 2 mm. in length, and with the ovipositor extruded, 6.2 mm. The antennæ are 0.8 mm. in length.

The male resembles the female, but bears a pair of conspicuous clasping organs at the end of the abdomen and has but fifteen antennal segments, all but the first two of which are pedicelled.

We have no other midge that I know of in a red clover field that may be mistaken for the seed-midge, tho in Europe the leaf-midge was originally described from red clover. Both midges affect white clover, however, but can be distinguished by the characters given on page 100.

Life History.—In central Illinois, the clover seed-midge winters as a full-grown larva, or as a pupa, in the soil of the clover field or in dead clover heads. A few warm days and a little rain bring the larvæ to the surface of the ground a few days after the red clover has started on its second year's growth. Thus in 1907, in Urbana, the first new leaves of red clover appeared March 19—a little earlier than usual—and the orange-colored larvæ of the midge were found on the ground from March 25 to April 4, inclusive, being most numerous March 30 and April 2. They are by no means abundant, however, at this time in a clover field of the second year, and would not be present at all but for the precocious development of some clover heads during the preceding season. Some of these larvæ make a cocoon and some do not. In either event the larva contracts in length and its integument hardens and becomes duller in color, forming a *puparium*, within which the pupa develops. One larva, found March 25, 1907, made a cocoon March 30, from which a female midge emerged April 12 or 13. A second larva, taken March 30, formed a cocoon April 2 and gave a female fly April 21. Both of these flies were reared indoors, it should be said. Out-of-doors, midges were not found until May 15, but were common May 23 (at which date oviposition was in progress) and attained their maximum numbers May 30. This season was a late one, however, owing to continuous cold weather in April, and in the years 1903 to 1906 inclusive the dates of maximum abundance were May 24 and 25, the time when young green clover heads also were most numerous. The larvæ work in the heads during June and the first week of July, and leave the heads when full grown and go to the ground to pupate. Our earliest date for the emergence of larvæ from the heads is June 20. Most of the larvæ emerge about June 30, tho not a few wait as late as July 8. The pupal period at this time is three weeks or more, and the flies of the second generation are most abundant in the last week of July and the first two weeks of August, tho scattering individuals emerge at almost any other time between the middle of July and the first of September. The egg period in early August is three days, varying a few hours, more or less, according to temperature. Most of the damage to the seed crop is done during the last two weeks of August and the first two weeks of September, when the larvæ are most numerous in clover heads. Most of these larvæ pass the winter as larvæ or pupæ, to emerge as flies the following May. A few larvæ, however, attain their growth early enough to produce flies in early September or even later, out-of-doors. Under the sheltered conditions of the insectary, but without artificial heat, flies appeared as late as October 10; and in a warm room flies will emerge from clover sod thruout the winter. It appears that the few flies of late September do not succeed in propagating their kind in this latitude, owing to the direct

effect of frost on the flies, but especially to the death of green clover heads before any larvæ therein can attain their growth. It is possible, however, that flies of early September produce larvæ capable of surviving the winter.

Thus there are in central Illinois two full broods of the seed-midge each year and a feeble third generation of flies, which belong essentially to the May brood of the next year. In the literature we find that maggots of the seed-midge emerged in immense numbers from clover heads in Washington, D. C., on May 23, 1880. This date would be one month too early for such an occurrence in this part of Illinois, where May 23 is ordinarily the time of maximum abundance of the first generation of flies.

Habits.—The eggs are laid always in green flower-heads, and chiefly during the warmer part of the day. With the aid of a hand lens, the process of oviposition can be observed, the female being frequently too busy to pay any attention to slight interruptions. The last four segments of the abdomen of the female are elongate like a telescope, forming a slender tapering ovipositor, twice as long as the remainder of the body and as flexible as a whip-lash. Standing on the outside of a green clover-head, the female inserts this organ among the florets and works it deeper and deeper until it can go no farther. The sensitive tip of the sinuous ovipositor finds a suitable spot for an egg and the female becomes quiet until the egg is laid. The entire process of egg-laying requires usually five minutes, and often ten to fifteen minutes. Tho the same female may lay several eggs in one clover head, she appears to make it a rule to distribute her eggs among a good many plants. Many females may, of course, oviposit in the same head, with the result sometimes that more larvæ hatch than can possibly find food. Thus in one head of eighty florets the writer found 106 eggs. Once in a while an egg is laid on a petal or on the calyx itself, but almost always it is glued to one of the hairs of the immature calyx, the glue often forming quite a perceptible mass. This is contrary to a published statement that the eggs "do not appear to be glued to the hairs."

The newly hatched larva has only one way of entering the ovary of a flower, namely, by squeezing in between the unopened petals, as Comstock said. Once inside the flower-bud, the maggot, incapable of biting any solid substance, sucks the fluid contents of the ovary, destroying the ovule or ovules. An affected floret presents externally a healthy appearance but the petals do not expand, except rarely. They remain fresh and pink until after the maggot leaves the bud, but eventually fade and wither away without opening.

The simplest way to get specimens of these larvæ is to collect clover heads that are partly green and partly in bloom, and to shake them up a little, when many of the larvæ will squirm their way out of the buds. The maggots often occur in great numbers on the bed of a hay wagon or the floor of a barn. In a tight glass jar of clover heads all the larvæ present will emerge, and the precise amount of infestation can be ascertained.

Tho the full-grown larvæ may simply drop to the ground, as other writers have stated, they frequently wriggle their way down along the stem of the plant, when the latter is wet with rain. Indeed, the larvæ, even when full grown, will not emerge if the air is too dry. Cecidomyiid larvæ in general require considerable moisture for their development and are very sensitive to the influence of humidity. Dryness causes the seed-midge larvæ, when on the ground, to squeeze themselves into crevices in the soil and to contract the body and become motionless, as if for pupation. Even then, however, moisture will repeatedly revive them to a condition of wriggling activity.

The period of pupation is lengthened by dryness and shortened by moisture. Prolonged dryness kills both larvæ and pupæ. Out-of-doors the flies do not emerge during a dry spell; continuous dry weather will delay their appearance as much as two weeks; but they may be expected to appear after a rain, in the appropriate part of the season. In the insectary, the emergence of the flies can be similarly controlled by moisture, as G. C. Davis has already noted.

Riley states that the pupa works itself thru its cocoon and to the surface of the ground when about to give forth the fly.

Autumn finds larvæ of various sizes in the clover heads, in central Illinois. Most of the larvæ become full grown and go to the ground in September; the rest remain in the heads and either finish their growth or else succumb to frost. In spite of frosts, full-sized larvæ may be found in the heads as late as the middle of October. October 28, 1907, we found in clover heads several larvæ which were so small (0.8 mm. in length) that they must have been derived from late September flies, and they were altogether too small to survive the imminent death of their food plant.

The recognized injury done by the seed-midge to red clover occurs during the second year of the plant, and the amount of injury increases the longer the plant is allowed to run.

Vigorous plants, however, form heads during their first year, and in these premature heads not a few larvæ of the seed-midge are to be found in autumn.

Natural Enemies.—The chalcid, *Bruchophagus (Eurytoma) funebris* How., at first suspected of being parasitic upon the larva of the seed-midge, is now known to destroy the seed instead of the larva, taking what the seed-midge leaves.

We have reared from clover heads containing larvæ of the seed-midge two as yet undetermined species of the chalcid genus *Tetrastichus*. These are possibly the same two that are mentioned by Webster as having been reared directly from both larvæ and pupæ obtained about Lincoln, Neb., in December. In Delaware, Sanderson bred from larvæ of the seed-midge, in October, 1899, and in June, 1900, parasites determined by Ashmead as *Tetrastichus carinatus* Forbes and *Torymus*.

Another parasite of the seed-midge is *Anopediæ error* Fitch, of the family *Platygastridæ*, a minute black species, about which almost nothing has been written since Comstock, in 1880, reported it as emerging from the cocoon of the clover seed-midge.

An energetic enemy of the seed-midge is the common flower-bug, (*Triphleps insidiosus* Say), as was found some years ago by Dr. Forbes. I have repeatedly found a nymph or an adult of this bug with its beak thrust into a seed-midge larva or fly.

Control.—It is by no means necessary to abandon temporarily the raising of clover seed on account of this insect, as was once proposed. The most effective and most practicable preventive is that given by Comstock, namely, to cut the first crop of clover as early as possible, in order to secure a good seed crop at the expense of a slight reduction in the hay crop. The good results of this method are frequently obtained, unconsciously, by farmers who make it a rule to cut their clover near the 17th of June. The writer was once sent by our State Entomologist to examine injured clover on the farm of A. E. Myers, at Millbrook, Ill. (Kendall Co.). At that place, August 19, 1903, there were twenty acres of red clover in full bloom, with the heads well filled with sound seed, with few green heads, and with almost no sign of the seed-midge; no eggs were found and only two midges were seen during an extensive search. This clover had been cut a few days before June 25. Across the road was another field of red clover, similar in history to the first except that it had not been cut until between July 4 and 10. Here none of the clover was in bloom, all the heads were green, and almost every head was loaded with eggs of the seed-midge; often there were more eggs in a head than there were florets. The flies were abundant also, and were still ovipositing. In this instance, a difference of two weeks in the time of cutting meant all the difference between almost complete immunity and heavy infestation.

Early cutting (1) results in the drying up of the food plant and the undeveloped larva, and (2) hastens the development of the second lot of clover heads, so that the midges of the second generation find but few green heads in which to lay their eggs.

The proper date for early cutting depends, of course, on latitude, weather, and other considerations. It should be not later than June 17 in central Illinois, and need not be earlier than June 7. Clover that is cut too green does not cure well, but the cutting need not be done until the field as a whole is fresh with bloom, tho it should not be delayed until the flowers have withered. A clover head half red and half green means that the seed-midge is present (or else the seed-caterpillar), and the grower who will take the trouble to study the habits of the midge will be able to cut his clover at just the right time to get rid of the seed-midge without losing much of his hay crop.

Similar results may be had by mowing back the clover as early as the middle of May, in Illinois and Ohio. This delays the heading enough to escape the second brood of flies.

Pasturing in spring and early summer exterminates the midge and yet insures a good crop of seed, so far as this insect is concerned. This method, as recommended by Dr. Fletcher, has been adopted with great success in Ontario, Can. There the first crop is pastured to cattle or sheep until the beginning of June but not later than the middle of that

month. In Michigan, also, the same method is successfully employed by dairymen, the clover fields being pastured until the 10th or 15th of June. (G. C. Davis.)

Contrary to what might be anticipated, the seed-midge neither flies far nor is carried far or in large numbers by the wind. Most of the midges that emerge in a clover field stay there and lay their eggs there. If the wind blows they cling to the clover plants or to the ground, or take but short and occasional flights. The direction of flight is, to be sure, determined by the wind if the wind is strong, and the midges are certainly disseminated more extensively by the wind than by their own powers of flight. Nevertheless, the number of midges carried from one field to another by the wind is, in the experience of the writer, comparatively small. For example, most of the midges in a given field of second-year clover on May 25 came forth in that field and were the offspring of the few midges that entered the same field during the latter part of the preceding year. Hence it would seem to be a wise procedure to prevent the sporadic heading of first-year clover by mowing it back a few weeks after the oats (or other small grains) have been harvested, at a time when the growth is vigorous, but yet sufficiently early to permit considerable further growth before frost sets in. This cutting need not injure the clover. In this state, red clover is not infrequently cut in the latter part of the first season, for a light hay crop, or to prevent premature seeding, and in the good growing season of 1907, some first-year clover hay (mixed with stubble) was put on the market. This cutting impairs neither the hay crop nor the seed crop of the ensuing year, provided it is done early enough to allow the plants to recover before winter. Volunteer clover should always be cut, as it affords a rich nursery for all kinds of clover insects.

Where clover and timothy are mixed, early June cutting will, in this latitude, sacrifice the timothy. To obviate this, pasture lightly or clip back the growth in May. This treatment, as Webster states, brings both the first and the second blooming of the clover too late for the destructive work of the midge, and the hay crop as a whole sustains no loss.

In a few reported instances, larvæ of the seed-midge have been found mixed with clover seed in bulk, and the theoretical danger of sowing such larvæ along with the seed has been pointed out. While we have no direct evidence as to the reality of this danger, it would be well, on general principles, to kill such larvæ, by drying them up under a gentle heat, which is said not to injure the seed, or by fumigation with bisulfid of carbon.

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CLOVER SEED-CHALCID

Bruchophagus funebris How.

This abundant and energetic chalcid, formerly presumed to be an enemy of the clover seed-midge, is now known to be itself one of the worst of the clover pests. Instead of being parasitic, like most of the chalcids, it eats out the clover seeds and reduces the seed crop materially.

The adults—little, compact, black, flylike insects—are common on clover heads that are fading and ripening. Seeds containing the larvæ of this chalcid become brown, brittle, and hollow, and when the clover is threshed, the empty shells left by the adults are swept away with the chaff.

Not until 1896 was this ubiquitous insect suspected of being a clover pest, and up to the present time its life history and habits have remained almost a blank, except for what E. S. G. Titus has written. The present account makes considerable additions to the knowledge of the subject.

Distribution.—Vermont, Rhode Island, New York, Delaware, District of Columbia, Virginia, West Virginia, Ohio, Indiana, Illinois, Michigan, Kansas, Mississippi, Minnesota, Colorado, California, Oregon, and Washington. Most of these records are from Titus, who reared the insect from clover heads obtained from various states.

Food Plants.—Red clover is the chief food plant, tho crimson clover is badly affected, according to Hopkins. Alfalfa is another food plant, but one of minor importance in my experience. I have not found the chalcid on white clover, but have seen the adults on mammoth clover.

Injury.—It was A. D. Hopkins who found that this chalcid eats the seed, instead of being a parasite upon some insect.

The larva requires a seed that is going to grow, and this need is provided for by the egg-laying habits of the female. She does not lay her eggs in green heads, but selects, primarily, heads that have just

begun to wither, and, secondarily, heads that are in full bloom. Sometimes I have seen her trying in vain to thrust her ovipositor into a seed that had hardened. The young larva feeds upon the semifluid albumen of the cotyledons of the seed; as the seed hardens, the jaws of the larva harden also, and at length the larva has eaten out the interior of the seed, leaving only a thin shell. Externally, an affected seed looks unhealthy. Instead of being blue, or clear yellow tinged with red or purple at the end, and plump, it is dull brown, often misshapen and a little undersized. At threshing time some of the adults have issued, leaving only the shells of the seeds, and these shells blow away, making an unaccountable shortage in the yield; other seeds, that still contain the insect, may remain behind with the sound seeds, but are of course good for nothing. These seeds that contain the insect are not necessarily so light that they blow off with the chaff, as one writer has assumed; many of them, if not most of them, are heavy enough to stay with the sound seeds, as I have often found. The empty shells are swept away. From newly threshed seed the adults may continue to emerge in swarms, as R. H. Pettit noticed. Thus the yield of seed is reduced in amount, and part of the yield made valueless, by this insect.

August 1 we examined 49 seeds taken at random, and found 35 to be sound and 14 to be infested by the chalcid; of the latter, 3 were



FIG. 1.—Clover Seed-chalcid, *Bruchophagus funebris*; adult female. (Webster, Circ. 69, Bur. Ent., U. S. Dept. of Agriculture.)

empty, 6 contained each a larva, 4 a pupa, and 1 an adult. Titus has found seed injured to the extent of 40 to 85 percent, with an average of 50 percent to the head.

Without examining the seeds there is no way of telling whether the chalcid is present or not, for the rest of the plant shows no indication of the presence of the pest.

Stages.—The adult (Fig. 1) is a minute, compact, flylike insect, mostly black, but with parts of the legs yellowish brown. It is small—the female being 1.9 mm. in length and the male 1.7 mm.—yet its actions on a clover head are so characteristic that one who has made the acquaintance of the insect can recognize it at once. Apart from its natural surroundings, however, one must look to certain minute details of structure in order to determine the species.

In the genus *Bruchophagus* the marginal vein is linear and not longer than the stigmal vein; the mesonotum is umbilicately punctate, and the abdomen ovate, pointed, and compressed in the female. The male resembles the female but lacks the point to the abdomen, and the

abdomen is shorter than in the other sex; while the male, unlike the female, has oval funicle segments and long antennal hairs.

The male of this particular species, *funbris*, is black and non-metallic. Eyes dark brown, antennæ almost as long as the thorax; flagellum of eight segments, there being five in the funicle and three in the club; the funicle segments have each a short apical peduncle, and all but the first of these segments have either two or three whorls of yellowish hairs—usually three on the second segment of the funicle and two on segments three to five. The knees, anterior tibiæ, and all the tarsi are light yellowish brown. The stigma of the wing gives off a feeble branch. The abdomen, joined to the thorax by a short, stout peduncle, is small, being less than half as long as the thorax, and its fourth segment is the largest.

The female is like the male in coloration but is larger, with these distinctive characters. Antennal segments not petiolate, and without the long hairs; flagellum of nine segments, the funicle having six and the club three. Abdomen not pedunculate, longer than the thorax, with the fourth and fifth segments short and subequal, and with a light brown pointed extremity—a part of the ovipositor.

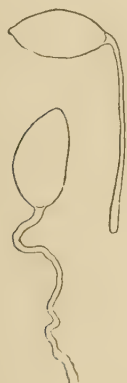


FIG. 2.—Clover Seed-chalcid, *Bruchophagus funebris*, eggs. Greatly enlarged.



FIG. 3.



FIG. 4.

Clover Seed-chalcid, *Bruchophagus funebris*: Fig. 3, larva, and head at right; Fig. 4, pupa. (Webster, Circ. 69, Bur. Ent., U. S. Dept. of Agriculture.)

The egg (Fig. 2) is broadly elliptical to ovate in form, ending anteriorly in a small papilla and prolonged posteriorly as a slender tube, at least twice as long as the egg proper, which averages 0.26 mm. in length. The egg when laid is translucent whitish, and smooth; within a day, the appendage shrinks and turns brown.

The maggotlike larva (Fig. 3) is white, stout, and footless, with a small head; length, when full grown, 1.5 to 2 mm. The larva shows few distinctive characters, tho it is stouter and less active than parasitic larvæ of the same family.

The pupa (Fig. 4) is for a time white, but darkens as the color of the imago develops; length 1.9 mm.

Life History.—In 1904 and 1905 we made daily observations on the number of adults emerging from clover heads collected thruout the season and kept in large glass jars—each lot having been collected at one time and place. The observations when plotted on coordinate paper showed several new things.

Beginning April 14, there was a gradual increase in the number of emergences up to June 6 and 12; then a rapid decrease to July 6; afterward a sudden rise from August 4 to a high maximum August 10, followed by a rapid drop to August 24, after which date adults issued constantly, but in moderate numbers, until October 15. Out-of-doors the adults do not begin to emerge until about May 15, as a rule, and in 1907 no adults were seen until May 23, tho the clover fields had been searched almost every day for them. The June and August dates of maximum emergence in the insectary agreed with the dates of maximum abundance in the field. One year, however, I found the chalcids common July 6 to 19, and very common about July 15, tho in most years there are but two times of greatest abundance, and these are when faded clover blossoms are most numerous in the fields of cultivated clover. Some adults can be found, however, almost any day in the season from May 15 to October 15, or later, especially on volunteer clover, where they can always find heads in just the right condition for oviposition.

The insect passes the winter inside the seed, on the ground. The seeds that we have collected and examined in early March contained larvæ only; in late autumn the seeds taken from dead clover heads on the ground contained many larvæ and now and then a pupa. Evidently the species winters chiefly, if not almost entirely, as a larva, in this region.

As the first period of egg-laying extends over a month or more, there is a corresponding range in the time of emergence of the second lot of adults. Thus, clover heads collected June 18 gave adults June 21 and every day from July 4 to July 20.

More than this, there occurs a surprising extension of the period of emergence. For example, heads collected June 21, 1904 (Urbana, Ill.), gave adults June 24; July 2, 4, 5, 6; August 9, 10, 11, 12, 13; then no more until the next year, 1905, when more adults issued May 27, 30, and June 5. Thus the last adults appeared almost a year later than the first ones—all these from eggs laid inside a period of one month. One to nine individuals issued on each of these dates, and the majority issued during the first year.

Compare this record with the above: Heads collected June 28, 1904 (De Kalb Co., Ill.) gave adults (in Urbana) July 2 (5 individuals); August 8 (1), 12 (4), 15 (1), 19 (1), and no more until 1905; then adults issued May 30 (2), 31 (2); June 1 (11), 2 (2), 3 (2), 5 (11), 6 (24), 7 (8), 8 (3), 9 (9), 10 (4), 12 (35), 13 (10), 14 (12), 15 (18), 16 (8), 17 (8), 19 (7), 20 (2), 22 (2), 24 (2), and none thereafter. Here, the great majority failed to emerge until the following year. Usually it is the other way.

By July 15 or a little earlier, new eggs begin to be laid in the new growth of red clover—the seed crop. We collected an immense number of clover heads July 28, 1904, which gave adults as follows: August 5 (many), 7 and 8 (194 individuals), 9 (42), 10 and 11 (13), 12 (103), 13 (23), 14 (6), 15 (31), 16 (6), 17 (2), 18 (1), 19 (3), 22

(8); then no more until 1905, when a few issued May 24 (2), 29 (3), June 5 (1), 7 (1); then no more—observations ceasing August 8. In this case, the majority emerged near the middle of August and the minority waited until the next year.

Taking heads collected still later in the season—August 26, 1904—these gave imagines August 30 (a few), 31 (a few), September 1 (few), 2 (few), 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 23, 25, 26, 29, October 6 (one individual on each of these last dates, with two exceptions); then, in 1905, May 12 (5), 16 (many), 19 (many), 20 (8), 23 (1), 26 (1), June 2 (1), and no more up to September 1, when the daily observations were discontinued.

Heads collected September 7 gave a few adults in September and October, but very many more in the following April and May.

Heads collected September 16, October 3, 17, and 27, gave no adults until the following April, May, and June, when large numbers issued.

In the last three instances most or all of the adults did not issue until the next year. Thus the time of emergence is delayed in proportion to the lateness of oviposition.

These records are by no means exceptional; they are typical; those given here were selected from some twenty as being the most complete and most significant for present purposes.

To summarize: The May and June adults lay their eggs in the first growth of second-year red clover, and most of the adults derived from these eggs appear in July and August, but some of them do not issue until the following May or June. The July and August adults lay their eggs in the second growth, and some of the adults from these appear during the same season; the rest not until the following year. The later the eggs are laid the larger the proportion of individuals to lie over until the next year. The adults have two times of greatest abundance, falling near June 12 and August 12 respectively. This does not mean only two generations, however, but, instead, two lots of individuals. The first lot (June 12) is derived from eggs laid thruout the previous season. The second lot (August 12) has no accessions from the previous year, but is, nevertheless, composite in its nature, for it consists of adults of both the second generation and the third. I have traced as many as three generations per year, and there is clearly a possibility of four. The fact that some members of each generation lie over until the next year complicates the study of the life history.

At first, it seemed to me at least possible that the prolongation of the period of emergence might really be due to re-oviposition in the old clover heads, even tho the chalcids had been removed every day as fast as they came to light and no copulation had been observed. This assumption was dismissed, however, after being tested, for the seeds were all too dry and hard to be penetrated by the ovipositor or to serve as larval food. There remained only the possibility that some chalcids had emerged soon enough after the clover heads were collected to

find seeds soft enough for oviposition, but this possibility was too slight to account for the immense number of late-emerging chalcids. Furthermore, any larvæ from eggs laid in the jars of clover heads would soon be disposed of by the drying and shriveling of the green seeds. I could not find any evidence of re-oviposition.

There is one source of possible confusion that must be guarded against in studying the life history of this chalcid. There emerges from the clover heads, along with *B. funebris*, another chalcid, *Tetrastichus bruchophagi* Ashm. MS., so named upon the assumption that it is a parasite of the clover seed-chalcid. This *Tetrastichus* is so much like the *Bruchophagus* in general appearance that it might hastily be mistaken for the latter, tho many differences between the two appear under the microscope.

Habits.—While the clover heads are green, in spring, few if any of the seed-chalcids will be found; but when they begin to turn brown, the chalcids appear on them. The males appear four or five days earlier than the females, and both sexes frequent the clover heads, but the males do not rush about and explore the recesses of the clover head in the way that the females do.

On warm sunny days the chalcids are most active, and then most of the eggs are laid. On rainy days both sexes remain quietly in the clover heads. They make their home among the florets, and there, at length, their dead bodies are to be found.

Brown ripe clover heads give the female much trouble, for she can not insert her ovipositor into a hard seed; green heads she passes by; florets in full bloom receive some attention and some eggs; but most of the eggs are laid in florets with withering corollas.

The males are quick to fly when one brings a hand lens near them, but the busy females occasion the observer less difficulty. The female squeezes in and out among the florets, often working her way deep into the flower head, so that one must cautiously spread the florets apart in order to follow her movements. Every now and then she stops to clean her antennæ with the front legs, or her wings and abdomen by passing the hind legs backward. With the tips of her palpitating antennæ she keeps touching the florets, especially the calyx, as if testing it. At length she proceeds to lay an egg, and usually pierces the side of the calyx tube, tho sometimes she stands on the top of the calyx, between the calyx lobes and the corolla. Bending the end of the abdomen forward under the body, she releases the long needlelike ovipositor and thrusts it into the calyx; then the abdomen recovers its normal form, but the ovipositor, at right angles to the body, remains inserted in the wall of the calyx, and is pushed and wriggled until its tip has entered the young seed. After three to twelve minutes the organ is withdrawn and rapidly slipped back into place. Sometimes a tiny colorless drop of fluid is seen at the tip of the ovipositor just before it is thrust into the calyx.

The observer, having identified the floret during the process of oviposition, can then pry it out with a knife and carry it back to be

dissected under a microscope, if he wishes to find the egg. The egg is found inside the seed in the semifluid albumen. Being translucent and almost colorless, the freshly laid egg transmits the pale green color of the surrounding seed tissue and is inconspicuous; but as one dissects the albumen carefully, the egg comes out like a lump of jelly, soft and delicate but sufficiently elastic to keep its form. The egg varies considerably in shape and must assume its definite form after leaving the ovipositor; for the body of the egg is wider than the channel of the ovipositor, and no distension of the organ is seen during oviposition. It is to be inferred that the egg passes thru the ovipositor in the form of a long thread, the body part of the egg entering the seed first and at once expanding. The usual position of the egg in the seed, with the end of the appendage near the seed coats and the body of the egg farther away, indicates that the body entered first. The appendage probably serves as a reservoir for some of the egg-contents while the egg is going thru the ovipositor. This appendage is empty in the freshly laid egg, and within a day after the latter is laid the former shrinks and turns brown—then affording a ready means of locating the egg. Without a careful dissection this delicate appendage will be missed.

The seeds in which the eggs are laid look sound and healthy and contain no other insect—so we have always found.

The egg, dissected out of a seed, can be kept for some time in a glass tube, upon a piece of moist black paper or a fragment of albumen taken from the seed, and can be examined daily under the microscope in order to determine the egg period. We kept eggs in this way for thirteen days, after which they appeared to be dead. Another way is to take a large number of seeds from florets in which the females were seen to oviposit, and to dissect these at successively longer intervals from the time of oviposition, making sure that there is not more than one egg in each seed. By this method I found that eggs laid July 22 were unhatched and apparently sound thirteen days afterward, but then the material gave out, and I do not yet know precisely the duration of the egg stage.

The larva when full grown fills the seed, leaving only the shell intact.

The adult emerges thru an irregular hole, generally at the top of the seed (as the seed stands in the calyx). In one instance I saw such a hole in the seed when the seed contained not an adult, but a pupa. The opening was no doubt made by the larva but was probably accidental—for among phytophagous chalcids in general the exit opening is bitten out by the adult, not by the larva.

Natural Enemies.—In company with the seed-chalcid, there emerged frequently, in our jars of clover heads, a second black chalcid which might casually be mistaken for the first species, tho belonging to another genus—*Tetrastichus*. The species is *T. bruchophagi* Ashm. MS., as determined from specimens named by Ashmead himself, and obtained by Mr. R. L. Webster from Prof. Lawrence Bruner. The

specific name may or may not prove to be appropriate in its meaning. At present I know of no direct evidence that the *Tetrastichus* feeds on the seed-chalcid, but the parasitic habit of other members of the genus, and the association of this species with the seed-chalcid, in the apparent absence of other possible hosts, leads one tentatively to regard the *Tetrastichus* as an enemy of the destructive clover seed-chalcid.

Control.—All things considered, the shortage of the seed crop, as a constant occurrence, is due chiefly to the seed-midge and the seed-chalcid, in this state. Probably the midge is a little more injurious than the chalcid; at least, the larvæ of the former are a little more abundant than those of the latter.

The chalcid has not attracted the attention that it will from economic entomologists, and nothing in the way of preventive measures has been proposed except the cautious statement by Webster that the same means recommended for the midge might apply to the chalcid, and that the destruction of outstanding clover heads and the burning of chaff and stems after hulling would in all probability greatly reduce the numbers of the insect.

It is safe to say that early cutting in June would undoubtedly prevent a great amount of oviposition, and if done as soon as the field came into bloom, would not only forestall most of the oviposition, but would also dispose of any eggs or young larvæ that might already be present in the tender green seeds; for the green unhardened seeds dry out and shrivel up soon after the leaves and stems dry. Moreover, early cutting of the hay crop would hasten the maturity of the seed crop in a way to prevent most of the midsummer oviposition; not all of it, of course, for some chalcids would be on the wing whenever the clover heads ripened. It is true, however, that the life history of the chalcid has become adapted to that of red clover as it is usually cultivated, and that the two periods of maximum abundance of the chalcid coincide with those of the greatest abundance of ripening clover heads; and it follows that the methods given would largely derange this adjustment.

The fact that the insect passes the winter inside the seeds on the ground indicates plowing under as a preventive. This is ordinarily done anyway after the second year of the clover, and when done at the usual time—as early as practicable in spring—the plowing doubtless buries most of the insects beyond the possibility of emergence.

In first-year clover the chalcid lays eggs in such heads as may be present in the latter part of the season, and these heads are often numerous. Their seeds, falling to the ground, furnish no small proportion of the chalcids that appear in the same field the following May and June. It would seem wise, therefore, to clip off or pasture off the heads of first-year red clover. In fact, something of a fodder crop can be obtained in the latter part of the first season without injury to the plant, if the cutting is not done too late in the season.

Volunteer clover is always infested by the chalcid, as well as by other pests, and ought to be destroyed.

I have several times examined commercial clover seed and found some of it injured by this insect, but the inmates of the seeds always happened to be dead. There is a strong possibility, however, that new clover seed takes the living insect to the field. Such seed, if sown broadcast, would permit the adults to emerge; but if drilled in, would dispose of the chalcids, as they could scarcely make their way to the surface.

Bruchophagus funebris How.

- 1880. Howard, L. O.—Rep. [U. S.] Comm. Agr., 1879, p. 196.
- 1896. Hopkins, A. D.—Bull. No. 6, U. S. Dept. Agr., Div. Ent., p. 73.
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- 1899. Pettit, R. H.—Bull. No. 175, Mich. Agr. Exper. Sta., pp. 366, 367.
- 1904. Titus, E. S. G.—Bull. No. 44, U. S. Dept. Agr., Div. Ent., pp. 77–80.
- 1906. Webster, F. M.—Circ. No. 69, U. S. Dept. Agr., Bur. Ent., pp. 7–9.

CLOVER SEED-CATERPILLAR

Enarmonia interstinctana Clem.

(*Grapholitha interstinctana*)

In its ability to diminish the seed crop, this pest ranks with the seed-midge and the seed-chalcid. Attacking a clover head that is green or partly in bloom, the little caterpillar eats out a cavity in the head, destroying many of the unopened buds and some of the tender green seeds, and spoiling the head as a whole. When no young clover heads are at hand, the caterpillar feeds on tender green leaves at the crown of the plant.

The adult is an inconspicuous little brown moth of the family *Tortricidæ*, and may be recognized by means of its peculiar silvery markings.

Distribution.—The published records show that this insect is present in Maine, Massachusetts, New York, Pennsylvania, Washington (D. C.), Ohio, Indiana, Illinois, Iowa, Missouri, and Michigan. It probably occurs in other states. In Illinois it is well established throughout the state, holding its own every year, and becoming locally abundant now and then.

Food Plants and Injuries.—The chief food plant is red clover, but white clover is also affected, and we have reared the species from alsike. Lintner quoted a correspondent to the effect that mammoth clover was not touched by a certain insect which Lintner (Eleventh Report, p. 153) took to be the seed-caterpillar. The correspondent's letter evidently refers, however, not to this insect at all, but to the seed-chalcid. There appears to be no reason why mammoth clover should

be exempt from the seed-caterpillar, and we have actually found it on so-called mammoth, which appeared to be a cross between mammoth and the common red clover.

Hatching usually near the base of a green clover-head, the larva eats into the head, destroying the green florets as it goes. A small green head is often destroyed entirely, before it is many days old; a larger head is injured only locally at first, remaining green on one side, while the other and unaffected side may come into full bloom (Pl. II., Fig. 9). To judge from the external appearance of the head, either the seed-caterpillar or the seed-midge larva might be the author of the mischief, and both are often present at the same time. A midge larva, however, is hidden away in the ovary of a single floret, while the seed-caterpillar makes a large dirty excavation involving many florets, and is readily brought to light by tearing open the clover head. The caterpillar attacks particularly the bases of the florets, and eats everything, including the semifluid ovules; occasionally it eats a soft green seed but it does not eat into seeds that have hardened. Not infrequently two larvæ are found in the same head. Even when the direct injury is confined to a portion of a clover head, the entire head is ruined, for it at length dries up and loses the rest of its florets, leaving only the dead brown receptacle.

Less conspicuous, tho not inconsiderable, is the injury at the crown of the plant, done chiefly in September and October, by caterpillars of the same species feeding on the young leaves.

The total amount of injury by this insect is, of course, variable. In New York, Comstock once found 15 to 20 percent of the heads of red clover infested. In Michigan, Webster saw clover injured to the extent of 95 percent. In Iowa, Gillette, Osborn, and Gossard have found the severest kind of infestation. While not sufficiently abundant to attract attention, the insect is, nevertheless, the unsuspected cause of a considerable reduction in the seed crop; for the destruction of one head by a caterpillar means a loss of more than one hundred seeds.

Stages.—The egg, hitherto undescribed, is at first green, then yellowish white, and is almost orbicular as seen from above, tho it is flattened ventrally; the surface is finely granulate and iridescent. The dimensions are as follows: length, 0.275 mm.; width, 0.26 mm.; and height, 0.21 mm.

The full-grown caterpillar, 7 or 8 mm. long, has the usual five pairs of prolegs. The color varies in accordance with the nature of the food (green tissue, or red floral tissue) from dirty white, tinged with green, to orange, as in Figure 10 of Plate II. The alimentary canal with its greenish or purplish contents shows thru the translucent skin and shifts in position as the caterpillar moves. The head is dark brown and polished, caudate occipitally, and deeply immersed in the prothorax. Prothoracic shield yellowish with a brown posterior border interrupted by a median line of white; or else dark brown with a clear median line. The body bears not a few pale stiff hairs, and the

dorsal piliferous tubercles are arranged, as Comstock noted, in two pairs, those of the anterior pair being closer together than those of the posterior pair.

Comstock has already described the pupa in detail. Essentially, it is 5 mm. long, brown, with the wing-cases and the dorsum of the thorax darker than the rest. There are two transverse rows of teeth on the dorsum of all the evident abdominal segments except the last, and the blunt anal segment bears posteriorly six stout blackish ex-curved hooks, and several delicate hooked filaments.

The oval white silken cocoon, 10 mm. long, is usually inconspicuous on account of the particles of excrement or bits of floral tissue attached to it.

The adult (Plate II., Fig. 11), expanding only 8 to 10 mm., is a silky dark brown moth, with brilliant silvery markings that are quite characteristic. The most conspicuous marks are those that make the two parallel crescents when the wings are closed. Along the anterior border of the front wing are eight silvery marks (sometimes nine) in form and position as shown in the figure. In fresh specimens the front wings show a few patches of iridescent scales. The hind wings are dark brown, with pale fringes.

Life History.—Our field and insectary observations show that there are three generations of this species every year, without much overlapping of the broods. Here, the moths of the first generation begin to emerge from the pupæ May 15, attain their maximum numbers May 24 (along with the clover seed-midge), and disappear during the last of June. In 1907—a late season—we saw no moths until May 21, and they were most numerous May 30. The moths of the second generation appear in the form of a few scattering individuals as early as June 25, but most of them are on the wing during the third week of July, and a few battered specimens linger over into the first week of August. The moths of the third generation appear as early as August 19, become abundant by August 30, continue to emerge as late as September 12, and die off by the last of September. Some margin—a few days—should, of course, be allowed for these dates, which are here given as they appear on our note-slips.

Eggs laid September 2 hatched September 7. The larval period is from one month to five weeks. The pupal period in July is between two and three weeks. It is possible to find larvæ of various sizes at any time from the last week of May until winter sets in, tho larvæ are few and far between when the moths are most numerous.

The moths of the third brood lay their eggs at once, and these hatch in five or six days; but the further life history becomes twofold, depending on where the eggs are laid. In the insectary the moths lay their eggs preferably on young clover heads, but if not supplied with these they oviposit erratically on fresh or dead leaves or stems. Out-of-doors in September and October the larvæ occur in two situations; either in immature clover heads, or at the crown of the plant. In the clover heads active larvæ can be found thruout October, in spite of the

frost, and a large proportion of these doubtless succeed in pupating before winter overtakes them. In the insectary, pupation in October is the rule. Larvæ which hatched September 7 spun cocoons October 14, and pupated October 16. One larva pupated September 2, and the moth emerged June 27.

The fate of the larvæ that feed at the crown of the plant in autumn is rather uncertain. The earliest ones probably pupate, and some of the remainder very likely survive the winter as larvæ. We have not been able as yet to find any of the larvæ in early spring, but in Iowa, following a year of heavy infestation, Gossard found full grown larvæ under rubbish and manure, and partly grown larvæ still in the crowns of the plants, April 22, tho the number found was only 25 percent of that found the preceding autumn.

Habits.—The moths appear in spring along with the first green heads of the red clover. When disturbed they take short rapid zigzag flights and come to rest on a clover plant. In the hot sunlight they seek the shaded side of a stem or the under side of a leaf, but in the cooler and darker parts of the day and in cloudy weather they often alight in full view, and close the wings, forming a little brown triangle marked with a silvery double crescent as in Figure 11, Plate II.

The moth, upon alighting, has the peculiar habit, already remarked by others, of whirling about in a circle several times, with the head as a pivot, and then reversing the movement before settling to rest. No explanation for this performance is evident.

Osborn and Gossard have reported the moths as being especially active in early evening, when they hovered over the clover blossoms in such numbers as to form a perfect cloud between the observer and the sun.

In clover that is forming heads, nearly all the larvæ are at work in the heads, but a few are present in unexpanded leaf-buds, eating out the interior tissue.

In first-year clover that has not headed, and in second-year clover that has been recently cut, the eggs are laid, singly as usual, on young stems and leaflets at or near the base of the plant, where the larvæ hatch and remain.

In first-year clover with oats, the moths are abundant in the new growth after harvest. Such was the case in a field in Urbana August 30, 1907, at which time none of the new growth had headed. In an adjoining field of second-year clover, the heads of which were nearly all brown, the moths had disappeared, leaving the seed-chalcid in charge of the crop. In September, a good many green heads occur on first-year clover, and in these the moths lay eggs rather abundantly. Volunteer clover is always infested by the seed-caterpillar.

The cocoon is spun in a clover head or at the surface of the ground, according to the situation of the larva. Comstock gives twenty to thirty days as the pupal period, and mentions that the pupa works its way out of the cocoon before giving forth the moth. Osborn and Gossard have found the pupa-cases in abundance on the ground, from which a brood had just issued.

Natural Enemies.—We have reared several braconid and ichneumonid parasites of the seed-caterpillar which await authentic determination. The following species have been published as parasites of this host: the ichneumonid *Glypta leucozonata* Ashm. (Proc. U. S. Nat. Mus., Vol. XII., 1889 [1890], p. 449), reared in Missouri by Miss M. E. Murtfeldt; the braconid *Phanerotoma (Sigalphus) tibialis* Hald. (Proc. Acad. Nat. Sci., Phila., Vol. IV., 1849 [1850], p. 203), raised in Washington, D. C., by Comstock; and a second braconid, *Microdus laticinctus* Cress. (Can. Ent., Vol. V., 1873, p. 53), recorded from Missouri, Iowa, Canada, and elsewhere. In Iowa, Osborn and Gossard have reared the last in abundance from cocoons of the clover seed-caterpillar, and have found that it corresponds exactly with its host as regards the number and the duration of the broods.

Gossard expresses the presumption that the braconid *Bracon veronicae* Ashm. (Proc. U. S. Nat. Mus., Vol. XI., 1888 [1889], p. 619) is a parasite of *E. interstinctana* in Iowa, since it is associated with the latter species in marked numbers and corresponds closely with it in time of appearance.

Control.—The best remedy for the attack of the seed-caterpillar is that proposed by Comstock, namely, to cut and store the hay crop early in June (New York, Illinois, Iowa), just as advised for the seed-midge, in order to kill the larvæ while still in the heads. The hay should be handled lightly and stacked or stored as soon as possible. Osborn and Gossard have attested the value of this method, and have given these further recommendations: (1) cut volunteer clover in early June and dispose of the heads speedily; (2) do not allow clover to run for more than two years; (3) sow seed on land remote from old fields; (4) pasture clover in the fall of the first year; (5) plow an old clover field under in October or November or in early spring, then harrow and roll. These practices operate at the same time against several other clover pests.

Enarmonia (Grapholitha) interstinctana Clem.

1860. Clemens, B.—Proc. Acad. Nat. Sci., Phila., p. 351.

1881. Comstock, J. H.—Rep. U. S. Comm. Agr., 1880, pp. 254, 255.

1891. Osborn, H., and Gossard, H. A.—Insect Life, Vol. IV., pp. 56–58.

Osborn, H., and Gossard, H. A.—Bull. No. 14, Iowa Agr. Exper. Sta., pp. 166–169.

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Osborn, H., and Gossard, H. A.—Twenty-second Ann. Rep. Ent. Soc. Ontario, pp. 74, 75.

1892. Gossard, H. A.—Bull. No. 19, Iowa Agr. Exper. Sta., pp. 571–589.

1896. Lintner, J. A.—Eleventh Rep. State Ent. N. Y., pp. 152–156.

PEA-LOUSE, OR CLOVER-LOUSE

Macrosiphum pisi Kalt.*(Nectarophora destructor)*

This is a big, green, long-legged plant-louse that has ruined millions of dollars' worth of field peas and a great deal of red clover. It is the dominant species of its kind on these plants (Fig. 5) and can scarcely be confused with any other aphid.

Distribution.—This pest was, in all probability, introduced with clover and peas from Europe, where it is widely distributed and common, tho it is reported mostly from England, Germany, France, and Italy. In the United States it has been injurious in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, Virginia, North Carolina, Ohio, Illinois, Michigan, Wisconsin, Minnesota, Nebraska, Iowa, Kentucky, and Texas. It is widespread in Canada also, occurring in Nova Scotia and New Brunswick and westward thru Ontario.

Not until 1899 did the louse attract the attention of American entomologists; in that year an outbreak in Maryland was reported upon by W. G. Johnson. He and E. D. Sanderson have written most of the literature on the species.

Our personal observations of several years, made as independently as possible, have yielded many facts that were already known and many that are new. The present account refers especially to the insect as it occurs in Illinois. In the eastern states the insect is chiefly a pest on peas. Here, where peas are not grown extensively, it is a pest on red clover.

Food Plants and Injury.—Under the name of "green dolphin" this aphid has long been known in Europe for its injuries to peas and vetches, and in minor measure to clovers and various weeds—some forty plants in all.

In America the aphid has done immense damage to peas and clovers. It affects especially leguminous plants, but numbers also



FIG. 5.—Clover-louse, *Macrosiphum pisi*, on stems of red clover. Natural size.

among its food plants many weeds of diverse families. The more important of its food plants are red clover, crimson clover, field pea, sweet pea, vetches (known also as "tares"), beet, lettuce, shepherd's purse, and nettle, not to mention the rest of the weeds. Alfalfa seems to be immune from attack. Thirty sweeps of the net in red clover yielded 3000 of the aphids, while the same number of similar sweeps in an adjoining field of alfalfa gave only 30. This alfalfa was mixed with some clover, however, and observations on the few lice that could be found on the alfalfa failed to find them in the act of feeding. On soy-beans growing next to heavily infested clover, not a single louse was found. Where crimson clover is grown, the aphid prefers it to red clover, it is said.

Where peas are grown, the aphid winters in a field of clover or on weeds (as a wingless female or as an egg), and in spring is confined to these until the peas start to grow, and then it does not get to the early varieties, tho it devastates the late-sown peas. In early spring most of the aphids are wingless and remain where they happen to be, but in late spring (May 1, Delaware) and early summer there are many winged females that can go from clover to peas and start an infestation. The first aphids select the youngest leaves and shoots, but eventually the lice cover the entire plant and sap out its life, rendering it unfit even for fodder.

In Wisconsin the louse was noticed in a five-hundred acre field of peas about July 20; in less than a week all the plants were dead and brown. In Maryland in 1899, the louse destroyed peas valued at \$3,000,000, conservatively estimated, and in 1900, \$4,000,000 worth were destroyed.

On red clover, the youngest leaves and stems are the first to be attacked, and these wither and die if many aphids are present. Wilted leaves mark the spread of the pest over the plant. Red clover, however, can stand a good deal of this injury, and if a heavy rain happens to occur when the plant is covered with the lice, they are washed off, and the field is safe for the rest of the season. There are also numerous insect enemies and a fungous disease, which kill off immense numbers of the lice. At times a combination of circumstances occurs, however, under which the plant is killed, root and all. The natural checks upon the increase of the aphid may be insufficient; but dry weather seems to be the most important factor. Without rain the plant can not replace the sap taken by the aphids, let alone make any growth; in dry weather the fungus can not develop; and in the absence of heavy rains to wash them off the plants, the aphids thrive. In dry weather, when the plants are loaded with lice, the cutting of the clover is the last straw.

In 1903 the louse killed an immense amount of red clover, and weakened much more, in De Kalb county. Being sent there by the State Entomologist, I found on the farm of Mr. A. E. Myers, at Millbrook, August 19, eighty acres of dead clover roots in one field. Not one root in a thousand showed any signs of life, and on the ground were thousands of the cast skins of the aphid. At cutting, the lice had

been such a nuisance that the men objected to handling the crop. After cutting, the clover never revived. In neighboring fields there were many bare spots where the aphid had killed the clover locally, and in the growing clover were many centers of new infestation, due doubtless to migrant winged females. All the clover in that part of the county was more or less injured; not only old clover, but also the first-year growth. Returning to the same region the following summer, to see the consequences of the injury, I did not stay long, for it was hard to find a field of clover anywhere. The farmers reported that the clover had been "winter-killed," to their surprise, since the winter had not been a severe one and the clover had often survived worse winters. The failure of the clover had discouraged almost all of them from sowing a new crop. My personal opinion was that the "winter-killing" would not have occurred had not the plants been weakened previously by the aphid. Clover is undoubtedly injured by certain winter influences, especially by being "heaved" out of the ground by frost, but there must be taken into consideration also the inability of the plant to face the winter when it has been ravaged by such insects as the aphid or the root-borer.

Only at rare intervals has there been a bad outbreak of this species. In England, according to Kirby and Spence, the havoc wrought by this aphid in 1810 was remarkable for its suddenness. Equally unanticipated was the outbreak of 1899 in some of the Atlantic states and in Canada. In 1900 the devastation continued in places where the previous injury had been worst, and a new outbreak occurred in Wisconsin. Since then no reports of serious damage have been published, but in Illinois this aphid was locally injurious in 1903, as just described, and has menaced the red clover every year from 1903 up to the present. Heavy rains subdue the louse almost every year.

Description.—The clover-louse is noticeably larger than any of the other aphids that frequent the field, the largest females being 6 mm. from tip to tip. The green color of the louse matches that of its food plant. The legs are conspicuously long, and the tarsi, distal ends of the tibiae and femora, as well as the tips of the cornicles, are fuscous. The antennae are darker at the joints, with the terminal filament fuscous. The eyes are red and prominent. With this general statement we may pass to a more detailed description of the species.

The generic term *Nectarophora* is antedated by *Macrosiphum* (Pergande, Bull. 44, Div. Ent., U. S. Dept. Agr., pp. 13, 14).

With the other species of its genus, *M. pisi* has the front of the head concave, with a large pair of tubercles supporting the antennae. The antennae, legs, cornicles, and abdominal stylus are exceptionally long in this genus as compared with other genera of aphids. The wings are large, the third discoidal vein has two forks, and the stigma is elongate-lanceolate. The terminal portion of the sixth antennal segment is very long and bristlelike. Most of the species of *Macrosiphum* are large and frequent herbage.

On the basis of Sanderson's studies we are obliged to regard this aphid (the *N. destructor* of Johnson) as the common *M. pisi*, of Europe, described long ago by Kalténbach.

The *alate viviparous female* (Pl. III., Fig. 1) is 4 to 5 mm. long, with an occasional maximum of 6 mm., and 1 to 1.5 mm. broad. Antennæ long, reaching to the tip of the stylus or a little beyond; first and second segments short and close to the tubercle; third to sixth segments related in length respectively as 3:2:1.5:4, the terminal filament of the sixth segment being three times as long as the base. Wing expanse about 11 mm. Fore wing 5 mm. by 2 mm. Cornicles slender, cylindrical, and long,—1 to 1.5 mm. Abdominal stylus half as long as the cornicles.

Sanderson gives smaller measurements thruout for the autumn winged viviparous female, it being only 3.15 mm. in length, with proportions varying a little from those just given.

The *apterous viviparous female* (Pl. III., Fig 2) is a little larger than the winged female, ranging in length from 4 to 6 mm., and the body is more elongate and fusiform, with longer cornicles (1.25 to 2 mm.) and a longer stylus. This form also is smaller in autumn, as Sanderson has noted, with much more extensive dark brown or blackish markings on the appendages.

The *oviparous female* is apterous.

The *egg* has not been described before. It is elliptical, twice as long as broad (0.5 mm. by 0.25 mm.), and changes from saffron-yellow to shiny black one or two days after being laid.

The *winged male* is 2.5 mm. in length, with a wing expanse of 9 mm. It may be recognized by its smaller size, among other things. The color tends toward pale green or yellow. The dorsal sclerites are dark, as is also the mesosternum, and there are lateral blackish spots in front of the cornicles. Sanderson has described this form.

Our insectary notes on one pair of *M. pisi* taken *in coitu* refer to the male as being apterous.

In autumn many of the aphids normally turn yellow; in fact, some yellow individuals can be found at any time, and aphids that are diseased usually do become yellow.

Life History.—The clover-louse winters both as a large wingless viviparous female and as an egg, but the eggs are not numerous. Many of the females are killed off during the winter. The survivors are easily found under rubbish in the clover field in the first week of April and even as early as March 25, tho they are a little slow to revive. They crawl to the clover plants and proceed to suck the sap and to bring forth living young, all of which are also females; indeed, no males appear until the last of the season and no eggs are laid until then. During most of the season there is nothing but a constant succession of females, all of them born alive. Most of them are wingless, tho in any of the generations there may be some females that have wings; these also bear their young alive.

The eggs that were laid on green leaves or stems the preceding autumn hatch a few days after the red clover starts on its new growth. March 23 Mr. E. O. G. Kelly found newly hatched young on a clover plant, and egg-shells close by on old dead clover leaves. One of these aphids, kept on potted clover, produced her first young April 5, and died May 12, after having brought forth ninety young.

Mr. R. L. Webster carried thru the season successive generations derived from a single female that came from the egg March 23, and obtained (by breeding always from the first-born) as many as seventeen generations, the young of the seventeenth brood issuing September 21 to October 3. In the field, newly born young can be found as late as November 4, tho we can not name the generation to which they belong. His more important data may best be given in the form of a table.

M. pisi

Generation	Birth	Maturity	Death	Days to mature	Days of life	Number of young
1	Mar. 23	Apr. 5	May 12	13	50	90
2	Apr. 5	Apr. 25	May 12	20	37	87
3	Apr. 26	May 8	May 13	12	17	25
4	May 8	May 20	June 16	12	39	89
5	May 20	May 31	June 9	11	20	49
6	June 1	June 10	June 20	9	19	41
7	June 10	June 19	July 17	9	37	37
8	June 19	July 1	July 17	12	28	60
9	July 1	July 10	Aug. 2	9	32	63
10	July 12	July 22	Aug. 3	10	22	30
11	July 22	Aug. 3	Aug. 15	12	24	44
12	Aug. 3	Aug. 11	Aug. 16	8	13	34
13	Aug. 11	Aug. 21	Aug. 30	10	19	16
14	Aug. 21	Sept. 1	Sept. 5	11	15	8
15	Sept. 2	Sept. 12	Sept. 15	10	13	10
16	Sept. 12	Sept. 21	Oct. 4	9	22	53
Averages.....				11	25.4	46

The averages are worth notice. A female begins to reproduce eleven days after birth, as a rule; this accounts for the large number of generations. The average number of young is not large for an insect, for insects as a whole average at least two or three hundred eggs per female. The average given in the table is confirmed by one based upon a large number of additional observations taken thruout the season. A female is, however, capable of producing as many as 147 young, and many of the females at death have embryos of various stages in their bodies.

The largest number of young produced in one day by one female is 13, and the average number 6, in our experience; while the bearing-period of the female averages 12.1 days. In October and November the females bear but few young, but some of these females hibernate and produce more young the following year.

Our breeding experiments, it should be said, were conducted indoors, where the aphids were protected from every source of danger. Out-of-doors the mortality would probably not be so small.

R. L. Webster's continuous observations on the life history are a useful addition to our knowledge of the species. His results are corroborated by those of Mr. E. Q. Snider, who, while a student at the

University of Illinois, made a similar series of studies. He began with the first hibernating females that he could find, and traced their progeny. One of the females found April 8 brought forth the first young aphid April 17, and this acquired wings April 29. In the field I have seen winged individuals at all times up to November 10.

Five apterous viviparous females studied by Snider bore, respectively, before the end of June, 104, 108, 110, 124, and 147 young. The last number is unusually large even for an aphid.

Males and oviparous females were not found until October (with one exception—a female born September 22); and males were taken in the field October 10, 17, 20, and November 3. Copulation was observed in the field October 20 and November 3; in the last instance oviposition began twenty-five minutes after copulation ceased. Six females began to oviposit, respectively, October 18, 20, 21, 31, and November 3 and 4. One female *in coitu* October 20 laid eggs October 26 (2 eggs), 29 (1), 31 (2), November 3 (1), 4 (1), 5 (1), 6 (2), 18 (2), and no more up to December 2, when the observations ended. A female born September 22 laid an unfertilized egg October 18. A female taken in the field October 11, 1904, laid eggs October 21, which hatched March 23, 1905. The eggs have escaped the notice of previous observers. Here, the eggs are common.

Habits.—When these aphids are as yet few, they select the youngest leaves and stems of the plant, especially the under sides of the leaves; but as they increase, they spread over the plant, and may crowd together so closely that large numbers fall to the ground for want of standing room.

The rapid increase in the number of individuals is not due to any extraordinary prolificacy, but results from the rapid growth and consequent early maturity of each aphid and from the fact that almost every individual is a female.

While the aphid is growing, the moults occur at short but variable intervals, as appears in the following table made from R. L. Webster's notes.

M. pisi

No. of generations	Born	First moult	Second moult	Third moult	Fourth moult	First young
1	March 23	March 28	March 31	April 2	April 4	April 5
1	March 23	March 25	March 31	April 4	April 9	
2	April 5	April 9	April 12	April 15	April 21	April 25
2	April 5	April 10	April 13	April 18	April 21	April 26
3	April 26	April 29	May 1	May 3	May 5	May 8
4	May 8	May 12	May 15			May 20
5	May 20	May 22	May 23	May 25	May 28	May 31
6	June 1	June 3	June 5	June 7	June 9	June 10
7	June 10	June 12	June 13	June 15	June 17	June 19
9	July 1	July 3	July 4	July 6	July 7	July 10
9	July 1	July 3	July 5	July 6	July 10	July 11

Thus there are four moults, or five instars, and the mother does not reproduce until after the last moult.

Another student (J. P. Gilbert) found five moults in one instance: an isolated female, born June 20, moulted June 23, 26, 27, 29, and 30. Each cast skin was removed as soon as found, and five of them were found.

More interesting than the number of moults is the fact that the females reproduce for many successive generations without the aid of the male—a normal phenomenon among aphids, and many other insects as well—and also the fact that the young are born alive. This can easily be witnessed, as aphids are so numerous. In this species the young aphid emerges hind end first and back upward, and enveloped in a delicate membrane, which it gets rid of by means of vigorous kicking. The entire process, requiring ten or fifteen minutes, is essentially as described elsewhere and in more detail for other species.

The mother does not wander much after beginning to reproduce, but stays in one spot, with the younger of her progeny clustered around her.

The winged females, which may occur in any of the seventeen or more generations, are the chief means of spreading the species. They are feeble of flight, but are often assisted by the wind to reach distant places.

Fertilization is evidently essential to the production of an egg that will hatch, tho eggs are laid whether fertilization has occurred or not. The deposition of an egg requires about seven minutes, as noted by E. C. G. Kelly, who observed also that the female used her hind legs to assist the egg out. A fluid that accompanies the egg serves to glue it to a green leaflet, on either side of which the egg may be laid. The eggs remain over winter on the dead leaves or stems on the ground.

In November there are still many mature females in the field, and they feed on mild days, crawling under shelter when the weather turns cold. If clover sod is brought indoors during the winter, the females appear with the new growth and the plants soon become overrun with aphids. Out-of-doors, most of the hibernating females meet their death sooner or later during the winter, in this region, notwithstanding the fact, reported by W. G. Johnson, that the species can survive severe freezing.

Natural Enemies.—The most important enemy of this louse is a common fungus, *Empusa aphidis*. It is wide-spread in the United States and Canada, and affects a great variety of aphids, its abundance, when it occurs, being proportional to that of its host. It does not appear in dry weather but is common after a rain or two at any time during the growing season, and is most abundant under the combined influences of moisture and warmth. Then it sweeps off myriads of aphids. Those killed by the epidemic remain clinging to the plant in a more or less lifelike attitude, but turn yellow and then light brown, become swollen, and eventually coated with the fungus (Pl. III., Fig. 3). The

appearance of the insect is at first similar to that caused by the presence of a larval *Aphidius* in the body of the aphid. The parasite, however, at length spins a silken cocoon under the aphid, and whenever present can easily be found by dissection.

The life history of this fungus is like that of *E. sphærosperma*, as given in some detail in the account of the clover leaf-weevil, and is discussed at length by Thaxter in the Memoirs of the Boston Society of Natural History, Vol. IV., 1888, pp. 175-177.

Macrosiphum pisi is affected, directly or indirectly, by a large number of other insects, of which other writers have recorded twenty. These and thirteen additional species are listed below.

Gryllidæ

Ecanthus confluens H. & H.
MS.

Pentatomidæ

Podisus maculiventris Say
(= *spinosus* Dall.)
Euschistus variolarius P. B.

Acanthidæ

Triphleps insidiosus Say

Chrysopidæ

Chrysopa oculata Say
Chrysopa rufilabris Burm.
Chrysopa plorabunda Fitch

Syrphidæ

Ocyptamus (Baccha) fuscipennis Say
Platychirus quadratus Say
Syrphus americanus Wied.
Syrphus ribesii L.
Allograpta obliqua Say
Mesogramma marginatum Say
Mesogramma politum Say
Sphærophoria cylindrica Say

Ichneumonidæ

Bassus lætotorius Fab.

Coccinellidæ

Megilla maculata DeG.
Hippodamia glacialis Fab.
Hippodamia convergens Guér.
Hippodamia tredecimpunctata L.
Hippodamia parenthesis Say
Coccinella novemnotata Hbst.
Coccinella sanguinea L.
Adalia bipunctata L.
Chilocorus bivulnerus Muls.

Lampyridæ

Podabrus rugulosus Lec.

Cecidomyiidæ

Diplosis sp.

Braconidæ

Perilitus americanus Riley
Trioxys (Praon) cerasaphis Fitch
Aphidius fletcheri Ashm. MS
Aphidius washingtonensis Ashm. MS.

Chalcididæ

Isocratus vulgaris Walk.
Pachyneuron syrphi Ashm.

Acarina, Rhyncholophidæ

Rhyncholophus parvus Banks

Most of these species I have studied in Illinois in their relation to *M. pisi*. Below is a summary of all that we know on the subject up to the present date. All these insects, concerned in one way or another with the clover-louse, are either predaceous or parasitic.

Coccinellidæ.—The omnipresent ladybird beetles and their larvæ are in this region the most efficient of the insect enemies of the clover-louse. The larvæ in particular destroy the louse in immense numbers. They are by no means limited to this aphid, but when it predominates, the number of *Coccinellidæ* present is a good measure of the abundance of the louse.

The hemispherical, brightly colored ladybird beetles (Fig. 6) are familiar, tho their larvæ are not so generally recognized. The entomologist knows them as active little alligator-like creatures, with a long warty or spiny abdomen. Some of them are blackish, but most of the common kinds are spotted with conspicuous colors. The pupa is attached by the tail to a silken support spun by the larva on a green leaf or other object. Its period is four to eight days, usually five or six in July, in the case of several of our common species. The yellow elliptical eggs, laid in small clusters, are conspicuous on green leaves and elsewhere.

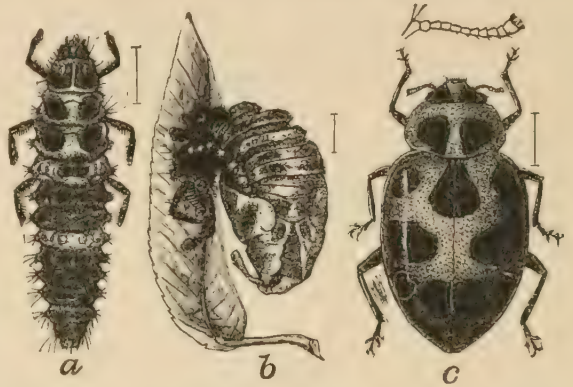


FIG. 6.—Ladybird, *Megilla maculata*: a, larva; b, empty pupal skin; c, beetle. (Chittenden, Circ. 43, Bur. Ent., U. S. Dept. of Agriculture.)

The yellow elliptical eggs, laid in small clusters, are conspicuous on green leaves and elsewhere.

Coccinellidæ in general hibernate as beetles, and all the species mentioned here do so. They are among the first insects to appear in the warm days of late March and early April. Comparatively few at the opening of the season, they multiply rapidly, tho in this respect they lag somewhat behind the plant-lice on which they feed, if the latter are at all numerous. *Coccinellidæ* feed also on scale insects, pollen grains, spores, etc., as Forbes found (Bull. No. 6, Ill. State Lab. Nat. Hist., 1883, pp. 33–64), but feed chiefly on plant-lice, and thus are beneficial.

Adalia bipunctata and *Hippodamia glacialis* were not often met with in the clover field, and *Coccinella sanguinea* was not numerous. *Chilocorus bixulnerus*, well known as a destroyer of scale insects, was rather common at times as an enemy of the clover-louse. The other species listed above were always common. *C. 9-notata* we noted as emerging as a beetle June 29, July 16 and 18; *C. sanguinea*, June 23; *H. 13-punctata*, July 15, 16, and 18; *M. maculata*, June 20, 21, 22, and 24; *H. parenthesis* issued July 1, 2, and 5, from pupæ found June 27; and eggs of this species, found June 14, hatched June 20, one of the larvæ pupating July 11 and giving the beetle July 15.

All the species listed were actually seen feeding upon *M. pisi*, either in the field or in the insectary. In the latter place, the diet of three *Megilla maculata* beetles included also (to their discredit) one coccinellid pupa, one adult *C. sanguinea* and two beetles of their own kind, besides some of their own eggs and (to their credit) eggs of the Colorado potato-beetle that were offered to them.

Perilitus americanus, a braconid parasite of the beetle of *Megilla maculata* and now and then of *C. 9-notata*, we reared several times from the former host. Parasitized beetles taken on clover leaves June 17, gave the winged braconid June 21 and 22; others, of June 23, gave

the adults June 30. My own experience with the parasite leads me to take no exception to the accounts already published by Riley (*Insect Life*, Vol. I., pp. 101-104, 338, 339) and by Weed and Hart (*Psyche*, Vol. V., pp. 188-190). Briefly, it may be said the beetle is found standing on a leaf and looking quite natural; indeed, it can still move some part of itself in most instances, tho it can not move away from the spot, for it is held by its feet to a brown mass of silk—a cocoon, from which the parasite will emerge in its winged form. The beetle may remain alive in this condition for two weeks and doubtless a little longer, but when disentangled from its foothold it is unable to move its legs in coordination—is unable to walk.

The larva that made the cocoon has issued from the beetle and could previously have been found inside the host, but some mystery exists as to where the larva makes its exit, for the shell of the beetle appears to be unbroken.

This *Perilitus*, then, is a check upon the beneficial ladybird beetle, but is of no practical importance on account of its infrequency.

On many occasions I have seen adults of *Podisus maculiventris* (*spinus*) and *Euschistus variolarius* sucking the pupæ of various of the coccinellids that prey upon the clover-louse. The eggs of both these pentatomids are heavily parasitized by a proctotrypid.

Syrphidæ.—Among the commonest insects of the clover field are several species of *Syrphidæ*, or flower-flies (Fig. 7, 8), some of which are known also as "sweat bees." Many of these flies are banded with black and yellow, and have the habit of poising over this or that spot for a few moments and making short dashes from one place to another. The flies lay their eggs in or near colonies of plant-lice, upon which the larvæ are to feed. The larvæ are leechlike in form, and generally green, yellow, or mottled brownish in color. They are often seen among the aphids, which they destroy at a rapid rate. The syrphid larva seizes an aphid between its hooklike jaws, holds it aloft and sucks the blood from the body, meanwhile waving itself to and fro. When full grown, the larva shortens and its skin hardens into a brown pear-shaped or elongate puparium, from which the fly will issue.

In this region the flies are seldom noticed in the clover field before the latter part of April, but are abundant by the last of May. The larvæ grow rapidly, and there are several generations of the common species each year.

In Maryland, Johnson found the syrphid larvæ to be the most important of the insect enemies of *M. pisi*, which they nearly exterminated in some localities. One pea grower sieved out twenty-five bushels of syrphid larvæ in a few days.

Allograpta obliqua Say, he found to be by far the most common and most important species, forming the greater bulk of the twenty-five bushels mentioned. He refers to the larvæ as being pea-green, slightly streaked with white, and one quarter to one third of an inch in length when full grown. The puparium is usually found on a leaf or stem, rarely on the ground.

Sanderson, in Delaware, found almost all the puparia of *Allograpta obliqua* to be parasitized by *Bassus latotorius* Fab., and from several puparia which seemed to have been parasitized by the *Bassus* were bred the chalcid *Pachyneuron syrphi* Ashm. *B. latotorius* is also parasitized by *Isocratus vulgaris* Walk., according to Fletcher.

A. obliqua is a common species in Illinois, where the larva feeds on *M. pisi* as well as on other aphids.

Syrphus americanus Wied., one of the largest species of the family, has conspicuous bands of black or yellow, and buzzes like a bee when on the wing. The larva is greenish or mottled brownish, attains a length of half an inch or more, and pupates on the plant or a little below the surface of the ground, as Johnson noted. The species deposits a single small oval white egg in a colony of plant-lice, and one of the larvæ has been observed to eat twenty-five plant-lice in as many minutes, according to Sanderson. In Delaware, he found it to be extremely abundant as an enemy of *M. pisi*; in Illinois, it feeds on the same species and is frequent but not conspicuously numerous.

Syrphus ribesii L. is reported from Canada, by Fletcher, as an abundant foe of the aphid, and as being attacked by *Bassus latotorius*, which, in turn, falls prey to the chalcid *Isocratus vulgaris*. *S. ribesii* occurs with us, but I have never happened to take it in the clover field.

Sphaerophoria cylindrica, a small syrphid named by others as affecting *M. pisi*, is rather common here in aphid-infested clover fields.

Mesogramma politum (Fig. 7, 8) is frequent in our clover fields, the green larva feeding on the clover-louse. A full-grown larva found on the ground March 27, made its puparium the same day, and the fly issued indoors April 8.

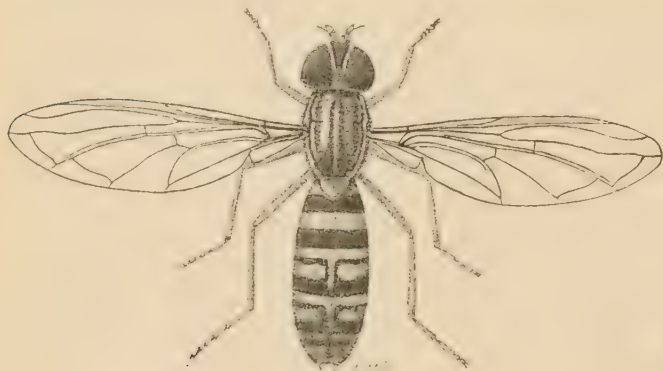


FIG. 7.

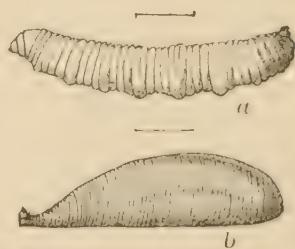


FIG. 8.

Syrphus-fly, *Mesogramma politum*: Fig. 7, adult; Fig. 8 (a), larva, (b) puparium. (Riley and Howard, U. S. Dept. of Agriculture.)

Mesogramma marginatum has similar habits and is common. A puparium found on a clover leaf June 21 yielded the adult June 22.

Platychirus quadratus, a small and frequent species, and the less common *Ocyptamus fuscipennis*, I have taken in sweepings, along with the abundant *M. pisi*. It is probable that their larvæ feed on the clover-louse.

Various syrphid larvæ that destroy *M. pisi* are themselves attacked by *Podisus maculiventris* (*spinosus*) and *Euschistus variolarius*; and the eggs of these pentatomids are parasitized by a proctotrypid, *Telenomus podisi* Ashm. (determined by A. A. Girault).

Chrysopidæ.—A few species of *Chrysopa* (Fig. 9) are common in the clover field. The adults, known as lace-wing flies, are green or less often yellow, with golden eyes and four similar gauzy wings, finely netted with veins. A few species have a characteristic odor—*C. oculata*, for example. By day the flight is rather sluggish, but toward evening the lacewings become more alert; they often fly to a light at night. Most of the species hibernate as pupæ, so far as is known, but *plorabunda* winters as an adult. We have often found it hibernating under dead leaves; then the insect is brown in color. Our species lay

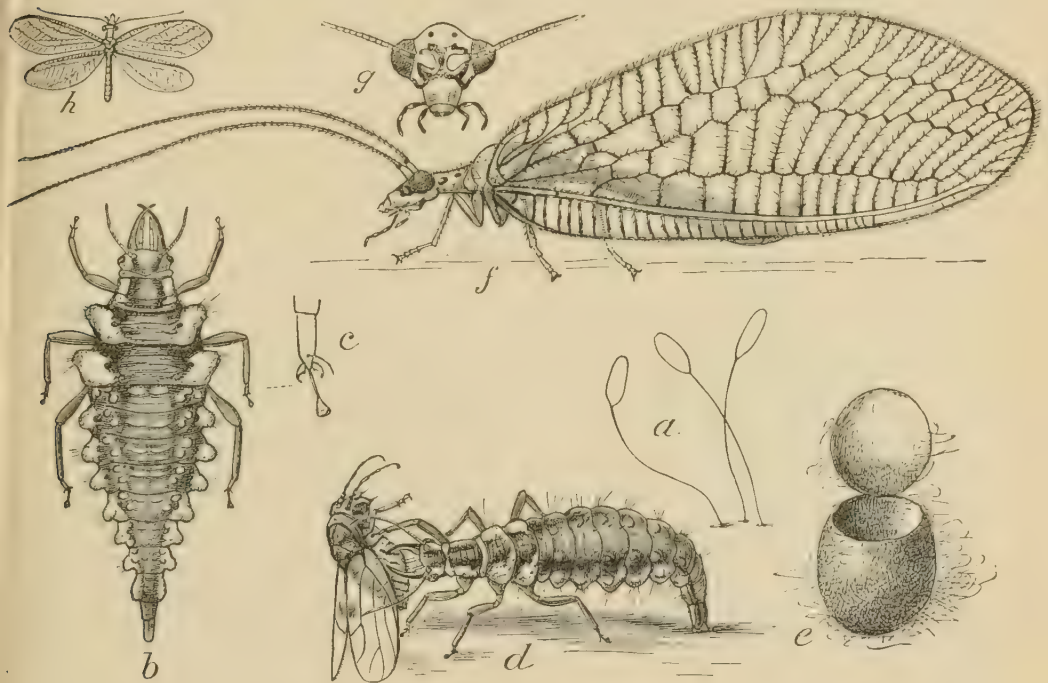


FIG. 9.—Lace-wing Fly, *Chrysopa oculata*: a, eggs; b, larva; c, foot of same; d, larva devouring pear-tree Psylla; e, cocoon; f, adult; g, head of same; h, adult, natural size. (Chittenden, Circ. 43, Bur. Ent., U. S. Dept. of Agriculture.)

their eggs each at the tip of a long stiff thread and always in the vicinity of plant-lice, which are the chief food of the larvæ. In clover fields the eggs are common on leaves or stems, and the larvæ eat ravenously *M. pisi* and other aphids, and eat one another now and then,—particularly when a lot of them issue at the same time from one cluster of eggs. The prey is seized between the points of the long, tapering mandibles of the aphid-lion and the blood is sucked back thru a channel made by a groove along the inner face of the mandible, against which the maxilla fits, to form a closed channel. A newly born larva,

unless cannibalistic, selects for its first meal a small tender aphid; under the microscope, one can see the watery juices of the victim bubbling along the transparent jaws of the captor. These larvæ are active creatures, gray, yellowish, or brownish in color, tho colorless at birth. They grow rapidly, and in one to three weeks spin a silken cocoon by means of glands opening into the rectum. The cocoon, spherical or oval, shows, after the emergence of the adult, a circular lid.

The *Chrysopa* larvæ are undoubtedly important checks on the clover-louse. In red clover I have found three species, namely, *oculata*, *plorabunda*, and *rufilabris*. The last was not common; but the first two were numerous, and their larvæ were frequently seen feeding on *M. pisi*, upon which we reared them in the insectary.

A larva of *oculata*, taken July 7, spun July 10 or 11 and gave the adult July 27.

A larva of *plorabunda* gave precisely the same record. A second larva of this species, taken in a colony of *M. pisi*, spun July 10, in a bent leaflet, the adult issuing July 20.

C. rufilabris emerged July 24 from a cocoon found on a clover leaf July 20.

We have reared no parasites of *Chrysopa*, but others have obtained from cocoons of this genus many species of chalcids and a few ichneumonids, and from the eggs one proctotrypid.

The most important of the predaceous foes of the clover-louse belong to the three families just discussed. There remain to be treated, several predaceous species of more or less importance.

While the seed-midge works havoc in the clover heads, another member of the same family is busily engaged in reducing the numbers of the clover-louse, at least in Canada, for all that we know about this helpful but undetermined species of *Diplosis* is what Dr. Fletcher learned at Ottawa, where in 1900 it was by far the most inveterate enemy of *M. pisi* on pea-vines. These minute orange maggots would transfix an aphid, hold it up, and suck out the blood, in much the same way as the syrphid larvæ. Their growth was so rapid as to result in several generations during the season. Winter was passed in a minute cocoon, spun on the stem of the plant or on the ground among grains of sand.

At Highland, Ill., August 11, I found on the red clover large numbers of both sexes of a tree-cricket (*Æcanthus*), and watched them devour the clover-aphid at a great rate. Afterward we kept these tree-crickets alive in the insectary for a long time and found it no small trouble to keep them supplied with enough plant-lice. Big, as compared with their victims, they soon cleaned a plant of aphids. One male ate nineteen full-sized aphids at one meal, lasting fifty-five minutes, an aphid being finished in ten to ninety-five seconds,—about one louse per minute on an average. In this instance, it should be said, Mr. Kelly facilitated matters by handing the cricket a new aphid as soon as the old one was finished. The same cricket, on the following day, being induced to repeat his performance, beat his previous record

by devouring eleven aphids in eighteen minutes, but fell short of his record for fifty-five minutes.

As an inveterate enemy of *M. pisi*, this *Æcanthus* is undoubtedly far ahead of Dr. Fletcher's *Diplosis* in capacity, but unfortunately does not appear to be wide-spread, tho it is probably common in southern Illinois.

This species of *Æcanthus* agreed with none of the published descriptions, but I found that Mr. C. A. Hart and Mr. J. D. Hood had seen the same species and given it the manuscript name of *confluens*.

Triphleps insidiosus, an active little flower-bug (Fig. 10) frequently impales *M. pisi* and sucks its blood. In our breeding experiments with the clover-louse this little intruder had to be excluded, as it played mischief with the birth-records.

Podisus (Fig. 11) and *Euschistus* (Fig. 12) as nymphs or adults destroy a clover-louse once in a while, as I noticed.



FIG. 10.—*Triphleps insidiosus*. Enlarged. (After Riley.)



FIG. 11.—*Podisus maculiventris*, nymph, sucking the blood from a caterpillar. Natural size.



FIG. 12.—*Euschistus variolarius*. Four times natural size.

The soldier-beetle (*Podabrus rugulosus*) was found feeding on *M. pisi* in Maryland, by Johnson.

A small red mite (*Rhyncholophus parvus*) was noted by Sander-son as feeding on *M. pisi* in Delaware.

Let us now turn to the parasites of *Macrosiphum pisi*.

Aphidius.—Often there is found on a clover leaf a dead aphid, light brown in color, with the body distended, attached to the leaf in a somewhat lifelike position by means of a little silken mat, which

spreads out under the aphid and raises it above the surface of the leaf. (Pl. III., Fig. 4.) This cocoon was made by a maggotlike larva that had been feeding inside the body of the aphid. The winged braconid emerges by cutting nearly a circle thru the skin of the host, usually thru the abdomen, and leaves a circular opening with usually a corresponding lid. The mother *Aphidius* inserts a single egg into the body of an aphid.

Two species of *Aphidius* are named in the literature as destroying *M. pisi*: *A. fletcheri* Ashm. MS., reported by Fletcher as having done good service in Ottawa, Can., and bred from *M. pisi* in Delaware by Sanderson; and *A. washingtonensis* Ashm., also bred by Sanderson under the same circumstances. In Delaware, at least 5 percent of the lice were killed by these parasites.

In Urbana, *Aphidius* is abundant every season on the clover-louse. We have had the adults emerge June 21, 26; July 1, 3, 4, 6, 8, 12, 17; August 18, 24; and October 18, 19, —mostly early in July, however.

An *Aphidius* larva that I found July 11 spun its oval silken carpet under the aphid on the same day; July 12 the aphid had been raised above the leaf and the cocoon was complete; July 18 the adult was found, it having issued during the preceding twenty-four hours. Another black larva spun June 18 and the imago emerged June 26. From a cocoon made October 12 the adult issued October 19.

October 10 a female *Aphidius* was put into a cage containing *M. pisi*, the individuals of which had been reared under glass in a way to insure their freedom from parasites. No oviposition was witnessed (the mother dying October 21), but November 16 three of the aphids showed the cocoons of *Aphidius*, the aphids having turned brown on the day before. These aphids were kept over winter in glass vials, and June 10 a winged *Aphidius* was found to have emerged. It was dead then, but certainly did not issue before March 17, when the vials were thoroly examined.

Another braconid, *Trioxys (Praon) cerasaphis*, was bred in large numbers by Fletcher from material collected at Ottawa, Canada, the material referred to being by implication *M. pisi*.

From what has been given it can be seen that a good many different insects have to do with *Macrosiphum pisi* in one way or another, and that the interrelations of some of them are involved. Thus, *Megilla maculata*, which eats *M. pisi*, is parasitized by *Perilitus americanus*, and preyed upon by *Euschistus variolarius*—the eggs of which are food for one of the proctotrypids. *Syrphidae* destroy *M. pisi* and are themselves food for the same *Euschistus*; furthermore, they are parasitized by *Bassus latotorius*, which, in turn, is parasitized by *Pachyneuron syrphi* and *Isocratus vulgaris*.

Among the natural enemies of this aphid is to be counted the English sparrow, according to a correspondent of Dr. J. B. Smith, who wrote, "It was wonderful to watch them, how soon they cleared up a pea-vine. After the sparrows commenced to work, they soon cleared up every louse."

Control.—The treatment of the pest is different according to whether the insect feeds on peas or on clover.

Growers in the eastern United States and in Canada have found that early peas are practically exempt from injury, and therefore plant the early-maturing varieties when injury is probable.

On peas grown for commercial purposes, spraying is too expensive, besides being in other respects impracticable, according to Johnson's elaborate experiments in Maryland. Sanderson found, in Delaware, some little advantage in spraying while the lice are still confined to the terminals and the vines are as yet upright.

A crop can be saved by the timely and thoro use of the "brush and cultivator" method devised by Johnson. This method requires that the peas be planted in rows 24 or 30 inches apart, instead of being sown broadcast. The lice are brushed off the vines with switches of pine branches or something similar, and are then buried under ground by means of a cultivator drawn by a single horse. Cultivation should not be repeated for three days, in order to insure the death of the buried lice. On a hot day, Johnson found that lice left on the surface of the ground died in a few minutes when the temperature of the air was 94°-96° F., and that of the ground 115°-119° F. In one instance, 600 acres of peas were saved in this way; and tho forty men were necessary for two weeks to brush and cultivate the peas, the crop netted the owner 25,000 to 30,000 cases of peas of two dozen cans each.

Instead of a cultivator a large shallow pan can be used, and the lice brushed into this as it is dragged between the rows by hand. In such a contrivance, containing a little water and kerosene, Johnson collected a bushel of lice to each row of 125 rods. The pan, made of galvanized iron, may be five or six inches deep, and as wide as the distance between the rows. Sanderson recommends this method as being perhaps the best one. It can be used when the soil is too damp for the cultivator.

Sanderson states that high fertilization (as with crimson clover and lime), with frequent cultivation for several years, often enables a crop of peas to mature in spite of the louse.

As the louse winters in the clover field and spreads from clover to peas, these should be planted as far from clover as possible. If the lice are abundant on clover in spring it may be advisable to plow the clover under, and roll the ground, in order to save the peas (Sanderson).

In gardens the louse can be controlled on green peas and flowering sweet peas by spraying, as with whale-oil soap (1 pound to 5 gallons of water) or kerosene-soap emulsion, diluted with 12 parts of water. Fletcher reports success with a spray of whale-oil soap and tobacco decoction. He put 10 pounds of tobacco leaves into half a barrel of water, strained off the liquid after a few hours, added 2 pounds of whale-oil soap, and, when this was dissolved, added enough water to make 40 gallons. Two days after the application of this spray to both surfaces of the leaves most of the lice were dead, and

such parts of the rows as had received two applications were cleared of the insects.

On red clover I have seen this aphid multiply in spring until its numbers threatened the life of the plant, and then disappear, practically, thru natural agencies; this for five successive seasons. A heavy rain did the work assisted by the fungus *Empusa aphidis* and, secondarily, by the numerous and important—tho somewhat lagging—predaceous and parasitic insect foes of the aphid. Were it not for these influences the louse would become a pest of the first magnitude in spite of the vigor of the clover plant. Occasionally and locally it does become such a pest, as already related.

Unfortunately, it can not be predicted whether the clover will be killed or not, and if one is unwilling to take the chances, the safest thing to do is to cut the clover just as soon as possible. Cutting and drying the clover will kill most of the lice at any time during the season.

The hordes of lice are for the most part the progeny of the fewer lice of May, in the same field. So it follows that spring pasturing or clipping back the clover would check the multiplication of the louse.

The lice of April and May are the progeny of a comparatively few wintered females that entered the field the preceding year, and also of a few eggs laid the previous autumn in the first-year clover. Therefore it is advisable to cut or pasture the clover in the latter part of its first season—and this will not hurt the plant if done intelligently.

Macrosiphum pisi Kalt.

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CLOVER LEAF-WEEVIL

Phytonomus punctatus Fab.

Tho this insect must be counted among the most important clover pests, it has not as yet established itself as an annual menace to the hay crop. Indeed, it is ordinarily held in check by a great variety of adverse influences, and seldom gets control of the plant—reminding one, in this respect, of the army-worm.

In early spring the larvæ make small round holes in the leaves of second-year clover, as soon as the leaves have begun to grow; later, they eat inward from the margin, the injury increasing in April and May. Thruout the summer the beetles gnaw the clover leaves in a ragged fashion and may even eat the plant down to the roots.

The larvæ and beetles are not seen in the daytime, unless one hunts for them; they are nocturnal in their activity. The larvæ, curled up under rubbish on the ground, are green with a white stripe along the middle of the back; they have no legs and are sluglike when inactive. The adults—tough, oval, brown beetles—are also found on the ground during the day, motionless, with the legs and antennæ drawn up against the body, or else moving away sluggishly when exposed to the light.

Distribution.—Tho this species has been familiar to European entomologists for more than a century, occurring as it does thruout Europe and in western Siberia, it was not recognized in this country until 1881, when its ruinous work was reported from Yates county, New York. At present the species is known to occur in Vermont, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, West Virginia, North Carolina, Ohio, Indiana, Illinois, Michigan, and Wisconsin, and also in Ontario, Canada. From the data collected by F. M. Webster, the insect appears to have spread from New York into Ohio, then westward; also from New York into Canada. At Ridgeway, Ont., Mr. A. H. Kilman found that the beetles were being brought by the east wind, August 10, 1884. On the same day, at Buffalo, N. Y., ten miles due east of Ridgeway and across the lake, the beetles swarmed on the pavements and could be collected by the quart along the lake shore. Reinecke noted their abundance in Buffalo following a heavy east wind.

Food Plants and Injuries.—The food plants in Europe are given as *Trifolium* (clover) and *Medicago sativa* (lucerne, alfalfa). In the United States the insect eats all kinds of clovers, and alfalfa as well. The other food plants that have been named, are beans and timothy for the larva, and burdock and the flowers of goldenrod for the beetle.

Webster observed a preference for white clover over red. In central Illinois red clover is most heavily infested, alfalfa coming second, and white clover third. Mammoth clover and alsike are freely eaten if they happen to be available.

European accounts refer but scantily to this species as a pest, aside from references to its devastations in Italy in the years 1867–70;

and in this country the insect, tho often abundant, seldom accomplishes the injury anticipated because the larvæ are usually killed in spring by a fungous disease. When this species cooperates with the root-borer, in a time of drought, injury of the worst kind may ensue.

The larvæ eat the leaves, and the beetles eat the leaves and stems also, as described later.

Description.—The egg is easily visible as a yellow object (chrome-yellow at first), elongate oval, 1.1 mm. long and 0.6 mm. broad. It darkens in from two to six days after being laid, and the surface is then rough, and sculptured with hexagonal depressions.

In the clover field the larvæ of this species (Fig. 13) can not easily be mistaken for anything else. They are green usually, and lie on the ground curled head to tail. Close examination shows that they are footless and have a brown head, while along the middle of the back is a white or pale yellow stripe edged with rose-red or black-



FIG. 13.— Clover leaf-weevil, *Phytonomus punctatus*, larva. Greatly enlarged.

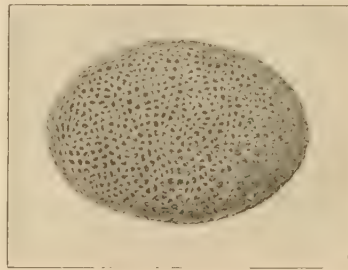


FIG. 14.— Clover leaf-weevil, *Phytonomus punctatus*, cocoon. Greatly enlarged.

ish red. The youngest larvæ, to be sure, differ from this description, for when only 1.5 mm. or 2 mm. long, they are white or pale yellow, with a jet-black head and only a suggestion of the characteristic median dorsal stripe; they are curled up on the ground and sluggish, however, just like the older larvæ.

Riley (1882, p. 178) gave a detailed description of the larva in its four stages. The body tapers gradually toward each end. The color, white at hatching, becomes green as soon as a meal has been taken. Some larvæ, however, are distinctly yellow instead of green, and a few are bluish green. The head, black in the first stage, becomes afterward brown or yellowish brown. The second stage (after the first moult) is marked by the appearance of the broad white dorsal line, bordered on each side by a blackish streak, and the length of the larva is 4 mm. After the second moult this line is more conspicuous and the length of the larva is 5 to 7 mm. With the third and final moult, the larvæ become decidedly green, tho the posterior part of the

body remains yellowish; the dorsal line becomes tinged with rose color and edged with blackish rose; length 8 to 14 mm. The cocoon is oval (Fig. 14), 9-10 mm. long and 6.5-7 mm. broad, and is composed of a coarse network of brownish threads.

The newly formed pupa (Fig. 15) has a yellowish green head, small black eyes, and yellow antennæ, legs, and wing-pads. The abdomen is dark green with a pale dorsal line, and bears numerous hairs at its extremity and a transverse series of dorsal setæ on each of its segments.

The beetle (Fig. 16) is a stout, oval, brown, finely punctured curculio. The female is about 8 mm. in length and 4.5 mm. in greatest width, some specimens being as long as 8.5 mm. The prevailing color



FIG. 15.



FIG. 16.

Clover Leaf-weevil, *Phytonomus punctatus*: Fig. 15, pupa; Fig. 16, beetle.
Greatly enlarged.

above is brown, but the sides of the prothorax and elytra are washed with pale yellowish brown, which on the elytra covers the outer five interspaces. Occasionally there is a pale sutural line. The elytra are marked above with small black spots, due to scales which occur at regular intervals on the interspaces. The prothorax is much narrower than the abdomen, subquadrate, and one fifth broader than long, with the sides rounding anteriorly and converging slightly posteriorly. The pronotum has three pale longitudinal lines, one in the middle and one on each side. The eyes are transverse. The beak is half as long again as the head, stout and curved, with deep antennal grooves. The scales and the short sparse setæ of the body are either brown or yellow.

The male, 7 mm. in maximum length, differs from the female in being smaller and narrower, with the sides of the elytra less rounded;

it is also darker in color than the female, with a narrower pale area on each elytron, the two outermost interspaces being dark instead of pale. The pygidium (which is not exposed) is, as usual in the family *Curculionidae*, divided by a transverse suture so as to form an additional, or anal, segment; thus the male has eight "dorsal segments" and the female seven.

P. punctatus is distinguishable at once from our other species of *Phytonomus* by its coloration, large size, and stout beak. As to smaller differences, *punctatus* is characterized by having mandibles that are not emarginate at the tip, while the first and second segments of the funicle are equal; in the other species of the genus the first segment is stouter and often longer than the second, and the beak is longer and more slender than in *punctatus*. In the clover field, this beetle will be recognized without difficulty.

Life History.—In central Illinois we have only one annual generation of this insect, as seems to be the rule elsewhere. All thru the winter small larvæ can be found in the clover field under rubbish on the ground or between the bases of the clover stems. In early spring the few warm days that start the clover on its new growth revive the larvæ also, and they begin to mar the fresh clover leaves with little round holes eaten out of the blades of the leaflets. In the early season of 1907 the first new leaves of red clover began to show March 19, and were already riddled by these larvæ March 23, at which date the larvæ were common on the ground near the affected plants. In early spring the larvæ are of many sizes, with an average of 5 mm. in length, tho many are only 2 or 2.5 mm. long, and a few are as long as 7 mm. I have rarely found the beetles in early spring, and such as were found were either dead or in the last stages of decrepitude, and evidently incapable of doing anything toward the propagation of their kind.

I have not found more than four larval stages—the number given by Riley. The first stage lasts about nine days, in the insectary; thus larvæ born November 16 moulted for the first time November 25. Some of the larvæ, born in late autumn, do not moult until the following March or April. For example, one larva was in its first stage April 1; it moulted April 8, April 17, and May 4, and spun May 20. The intervals between moults are, however, very variable, especially when the weather is unsettled, and the growth of the larvæ is consequently intermittent.

The pupal period indoors we have found to be 10 to 20 days, as in four instances following:

- (1) Spinning occurred April 22; pupation, April 24; emergence, May 11.
- (2) Spinning occurred April 22; pupation, April 24; emergence, May 14.
- (3) Spinning occurred April 24; pupation, April 30; emergence, May 20.
- (4) Spinning occurred May 20; pupation, May 27; emergence, June 6.

Larvæ of various sizes are common in April and May, but nearly all attain their growth before June 20. Rarely, beetles of the new generation appear as early as May 9; on that date we once found two

freshly emerged beetles in the field. The latest date for their emergence may be given as July 15. Many beetles issue daily from June 5 to June 30, and most of the beetles issue during the last week of June.

Early as the beetles appear, they do not begin to mate until the last week of August, and nearly all the eggs are laid in September and October.

We have insectary records of oviposition for almost every day between September 17 and October 26, and almost daily records of hatching from October 9 to November 27. The egg period in autumn is from 23 to 45 days, averaging 29 days; the length of the period depends upon temperature chiefly; some of the latest eggs, indeed, do not hatch until the following spring. Out-of-doors we have found eggs as late as November 14, and young larvæ as early as October 10. After that date they soon become common, and can be found at any time during the winter between the bases of the clover stems, as deep as possible, or else on the ground under more or less protection. Many of them succumb to the cold, however. These winter larvæ also are of various sizes. Sixty-five larvæ measured November 26 ranged in length from 2.5 mm. to 7.5 mm., with an average of 3.17 mm.

Late in October a few living beetles—more than three months old—occur in the clover field and go into hibernation. Early in the following spring their dead bodies may be found. Farther south, it is possible that enough beetles survive the winter to influence the course of the life history.

The preceding general account of the life history is based upon such a large body of observations that it represents the actual conditions with considerable accuracy, for central Illinois. A few precise notes are added on account of their significance.

Many eggs laid between October 16 and 25, 1905, were apparently sound January 21, 1906, and had not hatched February 23; but March 21, young larvæ from them were found, still alive, and 2 mm. in length. Again, eggs laid October 26, 1904, did not hatch until April 13, 1905.

I have several times followed the consecutive life history for a year or more. The longest account, covering a period of eighteen months, begins with a female beetle taken September 23, 1904. She laid eggs as follows:

Sept. 26, one mass of eggs.

Oct. 1, three egg-masses; hatched Nov. 3 and 4; larvæ alive Nov. 21, but died during winter.

Oct. 9, several eggs laid; they hatched November 19; the larvæ died in winter.

Oct. 26, several eggs laid; unhatched April 12, 1905; hatched April 13.

Nov. 1, three eggs; hatched Nov. 27, in warm room. The mother was alive Nov. 21, but died during the winter.

The larvæ that were born April 13, 1905, were reared; they buried

themselves in the ground May 23 and 24 and gave beetles June 13. Four of these beetles were kept alive until August 28, and August 29 one male and one female remained. The female laid eggs Oct. 16, 17, 21, 24, and 25. These eggs had not hatched February 23, 1906, but had just hatched March 21; by March 29 the larvæ had died, however, from a scarcely excusable neglect to supply them with food. The parent beetles had died the year before, about November 11.

This account of the life history is in some respects at variance with that of Riley (1882, pp. 175, 176). In central Illinois the egg period in autumn is from 23 to 45 days in the breeding-cage. Furthermore, none of the larvæ born in autumn give beetles in that season; the beetles do not emerge until the following June or thereabouts, and some of these are the beetles that will enter upon hibernation. In my experience, no eggs are laid in spring. In a warmer latitude than this there might very well be a second generation of beetles, to hibernate and to lay eggs the following spring. Indeed, in this latitude, the little autumn larvæ, if taken indoors and fed, will produce beetles in mid-winter.

Here, then, the clover leaf-weevil winters chiefly as a small larva; occasionally in the egg; never as a pupa, in my experience; and rarely as a beetle. No eggs are laid in spring, however, and there is clearly but one generation a year, tho this generation is straggling instead of compact.

Habits.—The larvæ that have hibernated are ready to eat the red clover as soon as it starts on its second year's growth. At any time during the winter one can get plenty of these larvæ by digging up clover sod and starting the growth of the clover indoors.

In midwinter, on a mild day (Jan. 6, 1903), the larvæ were feeding in abundance on red clover plants in Urbana, Ill. (R. D. Glasgow)—and in broad daylight. This is unusual, for at other times of the year they feed only at night or else at dusk or in daytime when the sky is sufficiently cloudy. Ordinarily, when the sun is shining they are found curled up in shaded situations, usually on the ground, but occasionally among the stems of their food plant. When feeding at night the larger larvæ drop to the ground when approached, but the smaller ones remain clinging to the leaflets, just as Riley observed. The larva frequently curls itself around the edge of a leaflet and bites out a small round piece from the blade; or it may secure a hold by gripping a hair of the leaf between two of its body segments. Only the youngest larvæ make the little round holes in the leaflets; the older larvæ eat gaps in the edges.

The feeding of the larvæ in spring is more or less intermittent, being suspended at every cold spell. In 1907, when the entire month of April was cold in central Illinois and frequent freezes blackened more than one third of the red clover leaves, the larvæ of the leaf-weevil, like their food plant, made no growth during the month of April, but became dormant again until May, tho they had been active during the warm weather of late March. Retarded in their develop-

ment by one month, they made up in May for what they had lost, and the majority of the beetles appeared at the usual time in June.

The locomotion of the larva is peculiar. The larva secures a hold on a hair by means of its mouth; then brings forward the end of the abdomen to secure a new hold, and stretches forward the rest of the body. Tho the larva is termed footless, it has, nevertheless, paired ventral fleshy tubercles which, from their anatomical relations, are evidently equivalent to the legs of other larvæ; also a median ventral prothoracic tubercle. These muscular tubercles assist in locomotion, especially on smooth surfaces. As the larva walks on the under side of a sheet of glass, slightly moistened, a suckerlike action of these tubercles is evident.

The color of the larva is white at birth, but a green tinge appears as soon as the larva has taken its first meal of green plant tissue. Some larvæ are yellow instead of green; diseased larvæ are generally yellow, tho not all yellow larvæ are diseased. Now and then a larva is found having a decided blue tinge.

When full grown the larva buries itself just under the surface of the soil and makes an oval cell, against the smooth wall of which it spins the cocoon; once in a while the cocoon is constructed among the bases of green clover stems. The cocoon, oval in form, consists of a coarse network of threads with round or oval meshes; it is pale yellow at first, becoming brownish with age. The actual spinning is done with the mouth. The first threads are laid in haphazard fashion across one another; but after a coarse framework has been made, the larva lays the later threads along beside the earlier ones, forming a stout network, and gradually reducing the meshes to small rounded holes. At intervals the supply of silk fluid in the mouth gives out; then the larva reaches back to the end of the abdomen and by an assiduous process of nibbling secures a new supply of the silk fluid from the rectum, and resumes its spinning. This performance always occurs, and can be observed easily with a hand lens in the earlier stages of cocoon-spinning. Riley and J. A. Osborne were each partly correct in their accounts of the spinning (Riley, 1882, p. 175).

The beetle eats its way out of the cocoon and enters upon a long and lazy existence of feeding by night and resting by day. Not until the last of August do the beetles arouse to reproductive activity. In summer they are sluggish in the daytime, under debris on the ground, but at night they are contrastingly alert. They reduce clover leaves to rags, beginning at the margins and eating inward, usually leaving the stout bases of the veins, but sometimes devouring the entire plant down to the ground—stalks, flower heads, and all. Incidentally, they spot the plants with a brown fluid. Like the larvæ, they are quick to drop when approached.

We have many times kept these beetles alive all summer, waiting for them to lay eggs. When the time comes they lay the conspicuous yellow eggs in profusion in the breeding-cages, with or without method, as the case may be. The female may scatter her eggs about promis-

cuously or place them in small bunches on the plant or elsewhere. In other instances she bites a hole in a clover stem and inserts an egg lengthwise, pushing it far in or leaving it sticking out of the stem. Sometimes she makes a cavity without laying an egg in it. Often the female eats her eggs. In a breeding-cage that is sufficiently shaded, eggs may be laid during the day; normally they are laid at night. Mr. R. L. Webster observed oviposition in our insectary October 16, beginning at 6:30 p. m. He found a female clinging to a clover stem, with her head downward, and piercing the stem with her rostrum, thrusting it in almost to the antennæ. At times she would raise the body on the front pair of legs as if throwing her entire weight on the beak. Having made a sufficiently large hole, she reversed her position and inserted a single egg; the actual oviposition took not more than twenty seconds. Then she made another hole but did not attempt to lay an egg in it.

Out-of-doors the eggs are found inserted into clover stems, but occur also, to some extent, on the base of the plant, where the stems join; rarely they are found on the ground.

The male often accompanies the female on her round of oviposition and there are repetitions of the process of fertilization, alternating with the periods of oviposition. September 25, a pair of beetles were put on potted red clover; Sept. 27, twelve eggs were laid; Sept. 28, six; Sept. 29, several; Oct. 5, several; Oct. 8, several more; Oct. 17, copulation occurred, probably for the second time; Oct. 23, more eggs were laid; Oct. 31, the female was missing.

The largest number of eggs that we have obtained from one female is forty.

Usually the female takes three or four weeks to lay all her eggs, under insectary conditions. In the field the period of egg-laying appears to be shortened, in the last of the season, by frost.

Our observations on the habits of this species are in accord with those of Riley, except as regards some minor details of locomotion and silk-spinning.

Natural Enemies.—Riley notes the larva of a small beetle, *Collops quadrimaculatus*, as feeding upon the eggs of the clover leaf-weevil, and *Cicindela repanda* as probably preying upon the larva of the weevil. In Europe various ichneumons parasitize *Phytonomus* larvæ, but in this country no such parasites have come to light as yet.

Webster mentions the fact that the larvæ are destroyed by birds, and that barnyard fowls, especially turkeys, are very fond of them.

The worst enemy of the leaf-weevil is an epidemic disease, that under favorable conditions sweeps off the larvæ by the wholesale. This disease, due to a fungus, needs damp and not too cold weather for its development, and affects the larvæ in April or May and again in October and November, but not during winter. The contagion is rapid and thoro; no matter how abundant the larvæ are, the infection spreads until, after two to four weeks, it is almost impossible to find a

living specimen. "The sick larvæ of all ages crawl up the herbage during the night, and instead of again concealing themselves near the ground on the approach of light, as the healthy ones do, ascend as high as possible, and if on grass, coil themselves in a horizontal position about the apex of the blade, or if on other objects, take a position as nearly similar as the shape of the object permits. If disturbed before the middle of the forenoon, the majority are still able to crawl, although sluggishly; by noon most of them are quite dead, but unchanged in appearance. It will be found that they cling to the leaf with greater tenacity than during life. Late in the afternoon, the body has changed from the normal yellowish or pea-green and smooth appearance to a velvety gray. The next morning there is only a small, blackened and shriveled mass remaining, while the surrounding foliage is powdered with a whitish, clinging dust, composed of the spores of the fungus. If some of the dead insects had been placed on a pane of glass, and a tumbler inverted over them during the night, they would have shrunk less, and been covered with a white fleecy growth, while on the glass, surrounding each body, would have been a white halo of spores two-thirds of an inch in diameter, such as everyone has observed about dead flies on the window in autumn. This is the general course of this rapid and fatal disease." (J. C. Arthur.)

This fungus, known as *Empusa (Entomophthora) sphaerosperma* Fres., is found in the body of the larva as a network of colorless branching threads (mycelium) which absorb the fluids of the body; some of the branches push thru the ventral wall of the body and attach themselves to the nearest surface as holdfasts (rhizoids); other branches pierce the skin and form a gray velvety coating on the body of the larva, and the tips of some of these branches each form a spore (conidium), which is finally projected forcibly into the air, to infect any other larva that it may happen to hit. These temporary spores germinate at once, pushing out one or more threads, which enter the host and grow, forming a mycelium. There are also resting spores; these develop within the body of the host and are capable of surviving for a longer period than the temporary spores.

Other and more technical details in regard to the fungus are given by J. C. Arthur (Fourth Rep. N. Y. Agr. Exper. Sta., 1885 [1886], pp. 258-262) and by Thaxter (Mem. Boston Soc. Nat. Hist., Vol. IV., 1888, pp. 172-175).

This fungus is by no means dependent upon the clover leaf-weevil for its existence, for it has a long list of hosts, representing most of the larger orders of insects. The list includes the common cabbage-worm, mosquitoes and some other flies, ichneumons, certain leaf-hoppers, etc. Fortunately, also, the fungus is widely distributed in America as well as in Europe. In this country the ravages of the fungus on the leaf-weevil have been reported from nearly every region in which the weevil has been injurious.

Control.—The reported outbreaks of the larvæ in spring have almost always been suppressed by the virulent disease just described. This disease prevents the summer damage by the beetles, often killing the larvæ before they have done much injury.

Riley's recommendation to plow badly infested clover under in May rather than to allow it to become a source of contagion, has seldom been followed unless the clover root-borer also has been present, for the leaf-weevil by itself has not often done an immense amount of damage.

The fact that the young larvæ hibernate, led Riley to mention the possibility of crushing them or burning them, but he added his doubt as to the practicability of killing them by rolling or by burning the clover stubble in winter.

The necessity for the employment of any remedy does not appear until the clover is well on in its second year's growth. If damage is anticipated, however, it would seem advisable to pasture the clover lightly or to clip it back in spring; this does not hurt the clover, is highly desirable as a means of forestalling the attacks of some other clover pests, and might check the larvæ of the leaf-weevil somewhat, tho it is possible that they would subsist on the cut stems until the new growth started; and in cold weather they can live a long time without any food.

After the second season red clover should be plowed under to get rid of this and other pests, as well as for agricultural reasons.

Phytonomus punctatus Fab.

1882. Riley, C. V.—Rep. [U. S.] Comm. Agr., 1881–82, pp. 171–179.

Lintner, J. A.—First Rep. Ins. N. Y., pp. 247–253.

1884. Kilman, A. H.—Can. Ent., Vol. XVI., pp. 144, 145.

1896. Webster, F. M.—Bull. No. 68, Ohio Agr. Exper. Sta., pp. 27–31.

CLOVER ROOT-BORER

Hylastinus obscurus Marsh.

(*Hylastes obscurus*, *H. trifolii* Müll., *Hylesinus trifolii* Müll.)

This pernicious root-borer is gradually spreading over the United States and Canada, and has already ruined crops of clover in New York, Ohio, Indiana, and Michigan. Often the injury done by this insidious insect has been attributed to drought or disease. The injury appears in the wilting and death of the plant. A badly injured plant breaks off easily at the crown; the roots are burrowed out lengthwise, and in the burrows can be found white footless grubs, or little, dark brown, cylindrical beetles, as tough in body as the others of their family, *Scolytidæ*.

Distribution.—This beetle was introduced from Europe, where it has been known for more than a century, feeding chiefly on red clover



FIG. 17.—Clover Root-borer, *Hylastinus obscurus*; work of insect. (Webster, Circ. 67, Bur. Ent., U. S. Dept. of Agriculture.)

but also on alsike. In this country it first attracted attention as a pest in 1878 in central New York. Thence it spread westward in the region of Lake Erie, doing great damage in Ontario, Can., in 1888, appearing in Michigan in 1889 at the west end of Lake Erie, and after that spreading over southern Michigan with disastrous consequences. In Ohio it was injurious by 1890, and seriously so in the northwestern part of the state in 1893. It has reached Indiana, Illinois, Pennsylvania, West Virginia, and North Carolina, and has even been reported from Oregon.

Food Plants and Injury.—In America the chief food plants are red clover and mammoth clover; others being alsike, alfalfa, and the pea.

First-year clover, its roots being small in spring, when the beetle lays its eggs, is not known to be attacked by this borer; second-year clover is attacked; and clover that has been allowed to run for more than two years harbors the pest in abundance.

An affected plant finally wilts and dies; when pulled by hand or by the mower it breaks off at the surface of the ground. The roots of such a plant are burrowed out longitudinally (Fig. 17), the burrows, with their walls more or less decayed, contain the excrementitious particles of the insect, and usually the insect itself in one or more of its stages, tho the beetles, being small, sluggish, and inconspicuous in color, are easily overlooked. Small cylindrical holes thru the sides of the roots are characteristic of this species, as indicating the emergence of beetles.

The amount and rapidity of injury depend not only upon the number of insects present but also upon the amount of moisture received by the plant. In dry weather the plant succumbs quickly to the borer, but in wet weather the plant, tho weakened, may continue to survive. Injured plants are liable to die late in June or early in July, after cutting; tho with plenty of rain many of the crippled plants may live until winter. In 1893 and 1894 the root-borer, in combination with the leaf-weevil and dry weather, caused a general failure of the clover crop in Michigan.

The borer is said to be responsible for an irregular, imperfect blooming of the clover or a failure to bloom at all. If the plants survive, thanks to copious rains, the yield of seed is liable to be almost nothing. In central Illinois the root-borer is generally distributed, but

is not a pest as yet, tho Mr. J. A. West, assistant to the State Entomologist, found alsike injured by it at Monticello in 1907.



FIG. 18.



FIG. 19.

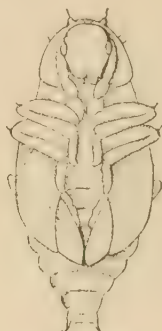


FIG. 20.

Clover Root-borer, *Hylastinus obscurus*: Fig. 18, beetle; Fig. 19, larva; Fig. 20, pupa. Greatly enlarged. (Webster, Circ. 67, Bur. Ent., U. S. Dept. of Agriculture.)

Stages.—The beetle (Fig. 18) is small—at most only 2.5 mm. in length—dark brown or blackish, cylindrical, hard-bodied and hairy. The elytra, or wing-covers, often have a reddish tinge, and are coarsely punctate; and the head and pronotum are more finely punctate, the latter bearing sparse long hairs. The tibiae have large teeth near the outer end.

The egg is minute, tho visible to the naked eye, white, and elliptical, with a smooth, shining surface.

The larva (Fig. 19) is stout, white, with yellow head and brown mouth parts, footless, and 3 mm. long when full grown.

The pupa (Fig. 20) is white, with a pair of spinelike projections at the extremity of the abdomen, and another pair on the top of the head. The pronotum shows a feeble median ridge and bears a few scattering bristles.

Life History and Habits.—There is but one generation a year. In Ohio, where Webster worked out the life history, the insect winters in clover roots as a beetle and also, tho less commonly, as a larva, the latter pupating in spring. The beetles leave the roots during May and fly about. The eggs are laid mostly from May 15 to June 20 in cavities eaten out by the females in the crown of the plant or down on the sides of the roots. In each cavity the female lays several eggs. Mr. G. C. Davis found females laying eggs inside the root, in the burrows, the eggs being packed into the dead wall of the burrow and covered with refuse. The larvæ, the first of which hatch late in May, feed for a time where they hatched, then tunnel along the roots, making one or more longitudinal galleries with occasional side branches, and filling the burrows with excrement. The pupa is found at the end of a burrow. Most of the larvæ pupate before the first of August and most of the pupæ transform to beetles before the first of October. The beetles

remain in the roots, however, until the following spring, feeding meanwhile, when they are not dormant.

In Ohio, according to Webster, larvæ and adults can be found at almost any time of the year, tho the beetles are rare in July. Pupæ are most common in July, but occur in August and even up to the middle of November, and a few pupæ, newly formed, are met with in early spring. Eggs have been found as late, or as early, as September 18 in Michigan.

Most of our articles on this insect have simply been based on the excellent accounts that Riley, Webster, and G. C. Davis published, and the species needs more study than it has received.

Here in central Illinois the life history and habits are as Webster found them to be in Ohio.

September 9 a pair of the beetles were observed *in coitu* in one of our cages. The conditions were not quite natural, however, for I had taken the beetles from roots and put them on potted clover; out-of-doors they probably would not have left the roots until spring. As soon as they were placed on the plant, September 8, they began to burrow into the crown; they mated the day after; October 3, a long burrow was found, containing several larvæ at its lower end, but no eggs; one of the parent beetles was still alive on November 21.

Only one natural enemy of the clover root-borer has been put on record—a telephorid larva, probably *Telephorus bilineatus* Say, mentioned by Riley as preying on the larva of the borer.

Control.—A badly infested field should be plowed as soon as possible after the removal of the hay crop, in order to starve the grubs by drying out the roots. The plowing must not be delayed, for early in July (latitude of Ohio, Webster) the larvæ begin to pass into the quiescent, or pupa, stage, in which they take no food; then they would doubtless transform and emerge as beetles in some numbers in spite of plowing.

In Ontario, Can., the value of clover as a green fertilizer is so generally appreciated that the farmers do not hesitate to plow the clover under at the first signs of the presence of the root-borer. (Fletcher.)

Another thing: Red clover should not be permitted to straggle along after the second year to furnish a nursery for this pest and others.

Fertilizers do not kill the root-borer and will not save the plant—so Mr. G. C. Davis concluded from his experiments with nitrate of soda, muriate of potash, and kainit. Generally speaking, fertilizers as used against a root-feeding insect act more by stimulating the plant than by affecting the insect directly.

Hylastinus obscurus Marsh.

1879. Riley, C. V.—Rep. [U. S.] Comm. Agr., 1878, pp. 248–250.

1880. Lintner, J. A.—Thirty-ninth Rep. N. Y. State Agr. Soc., 1879, pp. 41, 42.

1894. Davis, G. C.—Bull. No. 116, Mich. Agr. Exper. Sta., pp. 41–47.
 1896. Webster, F. M.—Bull. No. 68, Ohio Agr. Exper. Sta., pp. 31–33.
 1899. Webster, F. M.—Bull. No. 112, Ohio Agr. Exper. Sta., pp. 143–149.
 1905. Webster, F. M.—Circ. No. 67, U. S. Dept. Agr., Bur. Ent., pp. 1–5.

CLOVER HAY-WORM

Hypsopygia costalis Fab.

(*Pyralis costalis*, *Asopia costalis*)

The clover hay-worm works in stacked or stored clover, eating much of it, and contaminating much more with webs of silk and particles of excrement, making the hay unfit for fodder.

This species, described as long ago as 1775, has been sufficiently infrequent in England to be valued by the collector. It inhabits central and southern Europe, northern Asia, northern Africa, and a large part of North America. In this country its destructive work has been seen in New Hampshire, Massachusetts, Connecticut, New York, Maryland, West Virginia, North Carolina, Ohio, Indiana, Illinois, Kentucky, Tennessee, Alabama, Kansas, Missouri, Iowa, Nebraska, Michigan, and in Ontario, Canada.

In Illinois the species is widely distributed, according to the records of the State Entomologist, and has done no little damage in various parts of the state.

Injury.—The larvæ attack the bottom of a clover stack to a height of two feet or more from the ground; similarly, in the barn, they occur near the floor. They interweave the hay with white silken webs, intermixed with black pellets of excrement resembling coarse grains of gunpowder; they reduce much of the hay to chaff, and their webs give the hay the appearance of being mouldy; in fact, such hay actually becomes mouldy if it has been lying near the ground. This hay is refused by horses and cattle and is fit only to be burnt. When the hay is removed, swarms of wriggling brown caterpillars are left.

The pest evidently prefers dry clover hay. In mixed clover and timothy, the former is eaten and the latter is left, altho 50 percent of such hay may be damaged when the hay is three quarters timothy (Webster). One writer, it should be said, has reported serious damage to pure timothy in Kentucky. Webster reared the larvæ on growing clover heads, in the insectary, and, furthermore, obtained the moth in large numbers (June 3 to July 15) from masses of dead grape leaves taken May 5 on the ground in a vineyard. In summer the caterpillars are confined to the old unfed hay, and the infestation is worst on hay that has lain over, year after year.

Osborn mentions *Pyralis farinalis*, as well as *H. costalis*, as injuring stored clover hay in Iowa.

Stages.—The full-grown caterpillar (Fig. 21) is three quarters of an inch long, and dull brown with an olive tinge usually, tho some of the largest larvæ retain the pale color of the young larvæ. The head, shield, and caudal plate do not turn dark until after the last moult, according to Riley. The thoracic segments are much wrinkled, and most of the remaining segments are each divided by a transverse groove into two subsegments, the anterior of which is the larger. On each segment are several smooth shining areas, each bearing a fine white hair.

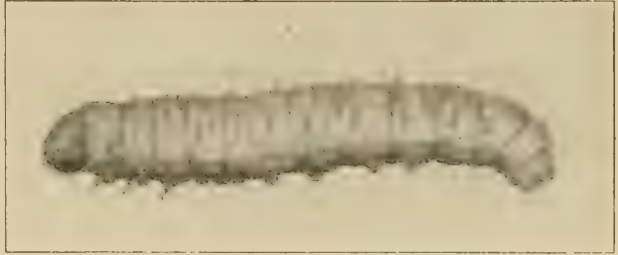


FIG. 21.—Clover Hay-worm, *Hypsopygia costalis*, larva. Greatly enlarged.

The cocoon is half an inch in length, oblong-oval, and composed of white silk, intermingled with excrement and bits of hay.

The chrysalis, as described by Riley, is honey-yellow, with the segments and members clearly defined by the darker color of the "in-sections."

The moth (Fig. 22) is small—the largest specimens spreading 22 mm.—and has silky wings tinged with purplish above, margined with orange, and fringed with golden yellow. On each of the upper wings are two large golden spots so situated as to divide the front margin of the wing into thirds; each of these spots continues backward to the hind margin of the wing as a narrow lilac line. On each hind wing are two wavy transverse straw-colored lines, one across the middle of the wing, and the other half-way between the first line and the base of the wing. Underneath, the



FIG. 22.—Clover Hay-worm, *Hypsopygia costalis*, moth. Twice natural width.

wings are pale yellowish with the markings indistinct. Head and legs straw-colored; antennæ and palpi pale orange, tinged with lilaceous.

Life History and Habits.—In Missouri and Ohio there are two generations a year and apparently more or less of a third brood. In winter, larvæ of all sizes are to be found in clover hay. In Ohio, Webster found pupæ no earlier than May 25; moths emerged June 12 and laid eggs June 13 to 17, other moths issuing from June 3 to July 15; young larvæ (very small to half grown) occurred July 1; larvæ and pupæ were seen August 6; and adults of the second generation began

to emerge August 8—larvæ from these being found August 15. In Connecticut, pupæ and many grown larvæ occurred June 7 (Britton); a pupa formed June 5 gave the moth June 18; most of the moths disappeared by July 15 (in a certain barn); the first larvæ of the second generation were taken in a stack of clover September 1; and larvæ were not found in barns until two or three weeks later.

In Illinois the hay-worm is destructive in winter and spring, as elsewhere. The records of the State Entomologist refer to its occurrence January 6 at Griggsville; February 4, Midland City; February 18, Shelbyville; March 25, Deland; April 6, Fillmore; May 21, Ridgefarm; and May 27, Parkersburg. A correspondent in Shelbyville reported the caterpillar from cheat, mixed with wheat and timothy.

The office notes include a great many records of the capture of the moths from June 2 onward. June 6, two moths, numerous pupæ, and a great many larvæ were present in a box of infested clover hay received from Parkersburg; and other moths issued June 10, 19, and 20. Dr. Forbes recorded moths of this species as being abundant July 10 to 20 and far less abundant July 28. They disappear about the last of July—those of the first generation—after flying thruout the months of June and July. The moths of the second brood appear a little before the middle of August. Moths are constantly seen from that time until the middle of October, but the last of these perhaps represent a third generation.

In the breeding-cage, eggs may be laid on growing clover heads, as appears from Webster's experiments, hence it is possible that the same thing occurs in the field.

Out-of-doors, the moths are seen flitting about clover stacks at dusk or in cloudy weather (June 29, Ohio). At night they often get into houses and fly toward the lights.

The caterpillars, of all sizes, can be found at any time during the winter, and in a barn they are active when everything outside is frozen. Warmth and moisture are greatest at the bottom of the clover, and there these caterpillars flourish. When you pick them up they are likely to wriggle out of your hand; they can wriggle backward as well as forward. They spin a lot of silk, and construct little silken cases for themselves, as do the clothes moths; they are continually spinning, and are often seen hanging from a thread of silk. These caterpillars are gregarious, or sociable; they gather together while they are feeding, tho they separate and wander when full grown and ready to make their cocoons.

No insect enemies of this pest are as yet known.

Control.—In a barn, old refuse clover-hay should be removed and burned if this insect is present, before new clover is put in. A stack of clover hay should be raised above the ground on a foundation of logs or rails, in order to keep the bottom of the stack as dry and cool as possible. It has been found that salting the hay at the bottom for two or three feet will preserve it from injury. Some farmers habitually salt their clover hay, using about two quarts of salt to the ton.

Webster's experiments indicate that the caterpillars can be killed at once in a clover stack by the use of pyrethrum. He had five tons of clover restacked, dusting it with this insect powder, using ten pounds of pyrethrum to fifty pounds of flour, and found in a sample of the hay that the majority of the caterpillars were dead the day after.

Britton, in Connecticut, tried bisulfid of carbon in a stack and hydrocyanic acid gas in a barn, but in both instances the clover had become packed so solidly that only a few caterpillars—those on the outer part of the heap—were killed by the treatment.

We need to know more about the life history and habits of this insect notwithstanding the large number of articles that have been written on the species, for these, with a few exceptions, add nothing to Riley's original account of 1874.

Hypsophygia costalis Fab.

1874. Riley, C. V.—Sixth Rep. Ins. Mo., pp. 102–107.

1891. Webster, F. M.—Insect Life, Vol. IV., pp. 121, 122.

1894. Davis, G. C.—Bull. No. 116, Mich. Agr. Exper. Sta., pp. 56–58.

1896. Lintner, J. A.—Eleventh Rep. Ins. N. Y., pp. 145–151.

1901. Britton, W. E.—Twenty-fourth Rep. Conn. Agr. Exper. Sta., 1900; p. 314.

CLOVER LEAF-MIDGE

Dasyneura trifolii Löw
(*Cecidomyia trifolii*)

This midge deserves some attention on account of its conspicuous effects on the leaflets of white clover, the leaflet being folded in halves along the midrib to form a sort of pod, which turns yellowish and at length brownish. Within this pod can be found white or orange maggots, or silken cocoons. The maggots change to minute flies—so small and inconspicuous as to interest only a specialist.

The economic importance of the leaf-midge is small, however, and nothing has been added to our published knowledge of the species since Comstock's account of 1880. Some new information appears in the present paper.

The species, long known in Europe, has been recorded from Washington, D. C.; it occurs also in Illinois, and in all probability is present in many other parts of the country.

Food Plants.—The leaf-midge feeds on white clover. In Europe it has been said to affect the undermost root-leaves of red clover, but I have not as yet been able to find it on that plant in this region.

The maggot does not fold the leaflet; the egg is laid before the leaflet has opened out, and after the larvæ begin to work the leaflet remains closed. It grows to a normal size, however, (Pl. II., Fig. 4) and continues to be green for a time, but eventually turns yellowish near the midrib, where the leaflet bulges out here and there, blisterlike.

As the gall gets older the blistered areas become specked with brown, and finally the entire gall turns brown and the leaflet dies. Inside the pod are the maggots—white or orange, according to age—and the white cocoons. The eggs are to be found only between the folded halves of the smallest leaflets, near the ground.

An affected leaflet continues to grow, and its forage value is scarcely diminished, but its death is hastened a little by the maggots. There is no effect upon the plant as a whole; when only one leaflet of a leaf is affected by the insect, the other two remain healthy for an indefinite time, but all three will at length wilt and die a little prematurely.

It can hardly be said that this insect actually injures white clover, taking everything into consideration.

Stages.—The egg has not been described before. It is like that of many other common midges, being elliptico-cylindrical with a slight curvature, colorless and translucent when laid, but showing an internal red spot on the second day—not before—and becoming pale orange in color. Length, 0.3 mm.; width, 0.075 mm.,—on an average. Several eggs are laid, side by side usually, as in Plate II., Fig. 5, in which the variation in the length of the eggs is to be laid to the midge instead of to the artist.

The newly born larva is colorless and transparent, and 0.27 mm. in length; soon it becomes white; when old it is orange (Pl. II., Fig. 6), and when full grown its length is 1.5 to 2 mm. The skin is coarsely granulate. The spiracular tubercles are arranged precisely as in the larva of the clover seed-midge—in fact, this arrangement is the same in several species that I have examined. The form of the sternal spatula (Pl. II., Fig. 7) is, however, different from that of *D. leguminicola*, the only species likely to be confused with this one as it occurs on clover.

The cocoon is oval in general outline, and 1.5 mm. long. Often it is flattened a little from contact with the leaflet or with other cocoons.

The pupa, orange in color, has a darker median ventral stripe, and blackish eyes, as Comstock says. The anterior border of the prothorax is deeply notched, and there are two long, excurved, mesothoracic horns.

Comstock gave a translation of the original description of this midge, which need not be repeated here. Rearing the midge from white clover, there is no difficulty in determining the species. Catching it on the wing, the leaf-midge needs to be distinguished from the seed-midge, which it resembles. Figures 3 and 8 of Plate II. show the differences between the two species. The leaf-midge (Fig. 8) is the smaller of the two, the female measuring 1.6 mm. in length. Both species have the red abdomen, but the dorsal bands of black scales are much larger and denser in *trifolii* than in *leguminicola*, and the scales do not rub off so easily, so that the abdomen in the former species is usually blackish. In addition, the leaf-midge has 14 or 15 antennal

segments, as against 16 or 17 in the seed-midge. The male, distinguishable from the female by the large clasping organs at the end of the abdomen, is also smaller than the male of the seed-midge.

Life History.—The podlike galls (Pl. II., Fig. 4) of the leaf-midge are common on white clover thruout the growing season, during which the insect in one or another of its stages can always be found in some of the galls. Usually several stages in the development of the insect are represented at the same time in a single gall. Frequently one to six individuals inhabit the same gall, and there may be more; I know of twenty eggs being deposited by a single female on one leaflet. Larvæ from eggs laid at the same time do not all develop equally; some of them outdistance the rest, and when the gall is crowded with the maggots, some of them die off in the competition for nourishment.

The earliest date that I have recorded for the galls is June 21, at which time larvæ and cocoons were present; thereafter I found the species in various stages every few days up to October 5, on which date larvæ were common. The latest eggs and larvæ are killed by the frost, along with the leaves which they inhabit. This fact in connection with what we know about the habits of the species warrants the inference that it probably winters in the cocoon, tho possibly as a fly.

My observations indicate four full broods a year in this place, with scattering and ill-fated members of a fifth brood. Each generation requires about one month, on an average, for its development. In the field the broods overlap enough to make their separation by field observations a little difficult. Yet there are times when almost all the galls are empty, indicating an interval between two broods, when the species is represented almost entirely by winged adults. Thus, August 14, 1903, when I examined a great number of recently made galls, I found 85 without living contents, tho remnants of cocoons were often present; 9 with cocoons (one to four in each instance); 2 with full-grown or large larvæ; and 2 with larvæ that had just hatched. Again, August 15, 1907, I opened several hundred of the galls and found nearly all of them to contain cocoons or full-grown larvæ; only one or two had white larvæ, and very many of the galls were empty, tho not more than a month old. Thus a break between two generations occurred about August 15 in two years.

Eggs laid August 1 gave six larvæ, the flies from which issued August 22; this is the shortest life history that I have found for this species. The egg period is six days as a rule; thus, eggs laid August 13 (2:45 to 3:15 p. m.) hatched August 19 (at noon). The period in the cocoon varies. From two cocoons made August 3, the imagines emerged August 13; in several other instances, nine days was the period. On the other hand, a larva that was making a cocoon August 5 did not give the adult until August 27.

Habits.—The midges can be obtained simply by picking the galls and keeping them on damp sand or cotton-wool. A better way, however, is to transplant such plants as bear the galls, because the leaves do not keep fresh very long after being picked.

To get the eggs and the subsequent stages it is only necessary to turn a lot of the midges loose on potted white clover under a lamp chimney (the narrow cylindrical kind) covered at the top with netting, making sure that the plant bears some young unopened leaves. It is best, also, to cut off most of the old leaves, especially in order to facilitate observation.

These little flies mate readily under such conditions, and lay eggs freely, as I have several times observed. After coition, which may not last longer than a minute, oviposition occurs within an hour or so. The female either drops to the ground or alights on the plant and walks downward. In either event she finds, after more or less exploration, a young leaflet still folded in halves. Standing at the base of this, she wriggles her long flexible ovipositor in between the two contiguous faces of the leaflet as far as possible; at intervals a slight wave of distention passes back along the ovipositor, indicating probably the passage of an egg. Usually several eggs are laid on the same leaflet—sometimes a dozen or more. After many eggs are laid, the abdomen of the female is noticeably smaller.

In some way the insect prevents the leaflet from opening out. The larva is quite unable to fold a leaflet that has already spread out. If placed on such a leaf the larvæ cannot even hold on to it, and rolls off. Like other midge larvæ, they require some tight crevice in which to develop.

Like them also, the maggots of the clover leaf-midge are very sensitive to moisture, contracting and becoming motionless when it is dry, and resuming activity when it is moist. Dryness prolongs the period of development and retards the emergence of the fly. The long record just given of twenty-two days from cocoon-making to emergence was due in some measure to dryness. The larva found making a cocoon August 5, was put into a small glass-covered box and pressed up against the glass by means of dry cotton-wool, so that I could watch the process of cocoon formation under the microscope. The larva spun for awhile, and then left its cocoon unfinished and wandered about, but it was contracted and motionless August 6 to 11. On the latter date the cotton was moistened, and soon the larva began to wriggle about in all directions, away from the light, and kept this up all day. Coming to rest again, the larva contracted without making a new cocoon, and gave an imago August 27. The larva often pupates without making a cocoon, if taken out of its gall.

The cocoon is evidently composed of silken threads, as Comstock said. Under the microscope the thread can be seen to issue from the mouth of the larva, which swings the fore part of the body to and fro as it spins. This fact is mentioned to counteract the old statement that the cocoon is an exudation around the body of the larva.

The leaf-midge is not without natural enemies. I have found the larvæ and pupæ of a chalcid in the galls among the midge larvæ. The chalcid is not common; I found it in only 1 percent of the galls, out of hundreds examined. The chalcid larva might hastily be mistaken

for one of the midge larvæ, as it has much the same size and color—white or orange. Its body is not so blunt as that of the maggots, however, and tapers anteriorly. Furthermore, the chalcid larva is far more active than a midge larva. While the latter wriggles about sluggishly and aimlessly, the former wriggles along hurriedly, as if it had some end in view. A few times I have seen a chalcid larva attack and feed upon a maggot of the midge, it being predaceous instead of parasitic. The chalcid becomes a naked pupa within the gall, among any of the maggots that may have escaped its attacks.

The clover leaf-midge needs no discussion from the point of view of control. Where the clover is frequently pastured or cut (as on lawns) it is hard to find any signs of the leaf-midge.

Dasyneura (Cecidomyia) trifolii Löw

1880. Comstock, J. H.—Rep. [U. S.] Comm. Agr., 1879, pp. 197–199.

CLOVER CALLIPTERUS

Callipterus trifolii Monell

This aphid is common in our clover fields every year, but has not been destructive as yet. It is far less numerous than the large green aphid, *Macrosiphum pisi*, and is not wide-spread and gregarious like that species, but is scattered, and rather solitary in habit.

C. trifolii, as found on clover, will be recognized, generally speaking, as a small yellowish green or yellow species with six longitudinal rows of dark tubercles on the abdomen.

This species has received almost no mention in our literature, largely because it has done nothing to attract attention. The material which we studied was determined tentatively by me from the original description, and positively by the author of the species, to whom specimens were sent by Mr. J. J. Davis.

Callipterus trifolii was described from Washington, D. C., by Monell, who found it again in Missouri. It is common in Illinois, and is reported authentically from Iowa, Kansas, Minnesota, North Dakota, New York, Delaware, and Virginia.

Descriptions.—The following descriptions, sufficiently detailed for the recognition of the species, and supplementary to the original description, are adapted from manuscript descriptions made by J. J. Davis, in cooperation with Monell.

The *viviparous females* (whether winged or not) are pale yellowish green. Eyes dark red to brown. Antennæ pale greenish basally, dusky apically, faintly imbricate, and as long as or a little longer than the body. Legs pale, dusky at the joints; tarsi blackish. Abdomen with six longitudinal rows of dusky setiferous tubercles. Style globular; cornicles tubercular; both a little dusky.

In the *wingless viviparous female* (Pl. III., Fig. 5) the dark abdominal tubercles bear conspicuous capitate hairs, and the length of the female averages 1.6 mm.

The *winged viviparous female* (Pl. III., Fig. 6) has a row of ten to twelve sensoria on the third antennal segment. Wings hyaline; veins dark brown to black, narrowly bordered with brownish, with a small brown patch at the outer end of each vein; basal half of stigmal vein obsolescent; discoidals as in the figure. The abdominal tubercles of the two inner rows are oblong, and each of them bears two fine setæ. The remaining tubercles, more or less circular, have each but one seta. Average length, 1.4 mm.

The *wingless oviparous female* is at first pale yellow, but the abdomen (excepting the last two segments) becomes progressively orange as the eggs develop in the body, and the orange color may eventually extend over most of the thorax. Eyes black. The antennæ do not reach to the cornicles, and the third antennal segment has eight or ten circular sensoria. Hind tibiæ swollen, and with sensoria. Dorsal abdominal tubercles essentially as in the winged viviparous female. Average length, 1.8 mm.

In the *winged male* the head and thorax are pale olivaceous green, and the abdomen pale yellowish green, with conspicuous black dorsal spots. Antennæ black (excepting the first two segments) and as long as the body, with sensoria as follows: 12-15 on segment three; 2-4 on four; 3-5 on five. Wings essentially as in the female. The large black oval setiferous spots of the abdomen fall chiefly into four rows—two dorsal and two lateral, with scattered spots between the former and the latter, on each side. Style and cornicles dusky. Average length, 1.2 mm.

The absolute lengths of the segments of the antennæ and legs, as well as those of the cornicles, are, as in other aphids, too variable to be of much importance as specific characters. The relative lengths are more constant, however, and hence more important for the systematist. They appear from the following table, which consists of the averages of many measurements made from Urbana specimens by J. J. Davis and from types of Mr. Monell—made by himself.

C. trifolii

	Antennæ						Style	Cornicles
	I	II	III	IV	V	VI		
Wingless viviparous female	.07 mm.	.05	.51	.34	.31	.15+.16	.17	.06
Winged viviparous female	.07	.05	.51	.36	.32	.16+.16	.13	.06
Winged viviparous female, Monell's types	.05	.04	.44	.31	.28	.15+.13		
Wingless oviparous female	.07	.05	.40	.19	.20	.13+.14		.06
Winged male	.06	.05	.51	.30	.29	.15+.15		.04

The egg, hitherto undescribed, is much like that of any other aphid in being elliptical, 0.57 mm. long, and 0.25 mm. broad, but has a characteristic bright orange-color when recently laid.

Life History, etc.—This aphid winters as an egg in the vicinity of Urbana, and I have found as yet no evidence that the female hibernates. The course of the life history differs but little from that of other aphids. The eggs produce viviparous females, and these constitute the successive generations up to the end of the season, when winged males and wingless oviparous females are brought forth viviparously. In this species, a large proportion—if not the majority—of the viviparous females are winged.

Beginning with a viviparous female which issued from the egg March 27, Mr. R. L. Webster followed the successive generations thru the season and obtained a maximum of nineteen, the final generation appearing October 18, in the insectary. The individuals of this generation were still very small on November 11, and disappeared thereafter. The more important of R. L. Webster's observations are given in the following table.

C. trifolii

Generation	Birth	Maturity	Death	Days to mature	Days of life	Number of young
1	Mar. 27	Apr. 20	May 9	24	43	36
2	Apr. 21	May 3	May 21	12	30	21
3	May 6	May 18	May 26	12	20	34
4	May 15	May 30	June 12	15	28	25
5	May 30	June 7	June 19	8	20	46
6	June 7	June 15	June 21	8	14	25
7	June 15	June 22	July 7	7	22	55
8	June 24	July 3	July 3	9	9	13
9	July 3	July 12	July 18	9	15	13
10	July 13	July 18	July 31	5	18	34
11	July 19	July 29	Aug. 3	10	15	23
12	July 29	Aug. 5	Aug. 22	7	24	70
13	Aug. 5	Aug. 11	Sept. 2	6	28	75
14	Aug. 11	Aug. 21	Sept. 9	10	29	60
15	Aug. 21	Aug. 28	Sept. 11	7	21	36
16	Sept. 10	Sept. 18	Sept. 28	8	18	20
17	Sept. 19	Oct. 2	Oct. 9	13	20	6
18	Oct. 2	Oct. 18	?	16	40+	?
19	Oct. 18	?	?	?	24+	?
Averages.....				10	22	34.8

The averages are made from the first seventeen generations. The number of young produced per day by one female ranges from none to thirteen, with an average of 3.7; and the bearing period of the female averages 12.1 days.

Comparing this table with that for *M. pisi* (p. 70) slight differences are apparent in the length of life and the period before maturity. These differences are of no weight, however, in view of the great variability of both species in both these respects. A few more observations would have changed, one way or the other, these averages, which are so nearly alike. The averages show, rather, that *M. pisi* and *C.*

trifolii agree essentially as regards the time from birth to maturity, the bearing period, and the length of life, the number of generations being essentially the same in both species. *C. trifolii* produces, however, only half as many young per day as *M. pisi* (3.7 young as against 6), and this difference serves to account for the relatively smaller numbers of *C. trifolii* in the field compared with *M. pisi*.

Wintered eggs hatched March 27, 28, and 29, according to our notes.

On red clover, brought into the laboratory in November, and grown, there were found, January 29, a large number of the orange oviparous females, which laid eggs in profusion. The average number of eggs in the abdomen of the mother is ten, as found by J. J. Davis.

The fungus *Empusa aphidis* attacks this plant-louse thruout the season, in damp weather, just as it does *M. pisi*; and many of the insect enemies of the latter species attack *C. trifolii* also.

Callipterus trifolii maintains its existence every year, but has always been a sporadic species.

Callipterus trifolii Monell.

1882. Monell, J. T.—Can. Ent., Vol. XIV., p. 14.

1908. Davis, J. J.—Ann. Ent. Soc. Amer., Vol. I., pp. 256-258.

CLOVER STEM-BORER

Languria mozardi Latr.

The stem-borer is of but secondary importance among the injurious insects of clover; it has never been a pest, so far as I can learn.

The slender yellow larva eats out the pith of the clover stem, making a long burrow, with brown discolored walls. The entire development takes place within the clover stem, and the adults fly abroad as slender beetles with dark blue wing-covers, and red thorax and head.

Tho the beetle is well known to collectors, scarcely anything has been published on its life history since Comstock's brief account in 1880.

Distribution.—This species was originally described from North America, and the genus *Languria* does not appear in the catalogs of European beetles. In this country *L. mozardi* has been reported from Pennsylvania, the District of Columbia, Indiana, Illinois, Michigan, Kansas, Nebraska, and elsewhere. Generally speaking, it inhabits the middle and the southern states, some of the western states, and parts of Canada.

Food Plants and Injuries.—The clover stem-borer is by no means limited to red clover and mammoth clover, but feeds also on the following plants, as C. M. Weed, Chittenden, and Webster found: wild

sweet clover (*Melilotus alba*), pink fleabane (*Erigeron philadelphicus*), daisy fleabane (*E. ramosus*), mare's tail (*E. canadensis*), ragweed (*Ambrosia trifida*), coneflower (*Rudbeckia laciniata*), yarrow (*Achillea millefolium*), oxeye daisy (*Chrysanthemum leucanthemum*), thistle (*Cnicus altissimus*), wild lettuce (*Lactuca canadensis* and *L. floridana*), bellflower (*Campanula americana*), nettle (*Urtica gracilis* and *U. dioica*) and timothy (*Phleum pratense*). Most of these are *Compositæ*, it will be noticed, and nearly all are weeds.

Injury.—The beetles do not lay their eggs in seedling clover, but find clover that is more than one year old and select only the larger stems of that.

By autumn, red clover sown in spring has developed stems of considerable size, and the beetles are present—but they do not lay eggs in autumn, in my experience.

The larva, by eating the pith, hollows out the clover stem, making a long burrow, the walls of which turn brown. By cutting stems across, beginning near the ground, and looking at the cut ends, one can see whether the pith is white and solid or whether it has been eaten out by this borer. The larvæ eat usually nothing but the pith, which happens to be the part that the plant can best afford to lose.

Comstock wrote, "While they do not kill the stem outright, they gradually weaken it and eventually cause its destruction, having also, of course, a very injurious effect upon the maturing of the seed." Undoubtedly the insect is injurious, but it is not so injurious as might be supposed. The loss of the pith may affect the nutrition of the plant to some extent, since the pith contains reserve food-material in the form of starch. The chief effect of the stem-borer is, however, a mechanical one. The stems that are hollowed out fall to the ground prematurely, tho not until they have attained a considerable size. One can find the borers most abundantly in the large prostrate stems rather than in the stems that remain erect. The plants that lodge carry their flowers to the ground, become soiled with dirt, and are not easy to mow. Mammoth clover, running far into the season, lodges badly from the work of the borer; while medium red clover, if cut when it should be, escapes practically all injury from this insect.

Rarely the borer occurs in a small soft stem and causes it to wilt; for in such a stem the larva eats not only the pith, but also some of the adjacent ducts, thru which water is conveyed up the stem to the leaves. In old stems these ducts are too tough to be eaten by the larva.

Were this insect more numerous it might gradually develop into a pest of considerable importance. It is most common on clover, but has to its credit the fact that it affects also a considerable number of weeds.

July 6 we found 41 percent of the old stems to be infested by this borer. This was in the hay crop—as yet uncut. On the same day we examined 61 new stems—the second growth after cutting—and found two egg pits as the only signs of the borer. The beetles

had disappeared, almost without exception, by this date. July 7, 43 percent of the old stems, taken from many different places—roadside as well as field—contained the insect.

Stages.—The beetle (Fig. 23) is conspicuous on account of its slender form, dark blue wing-covers, and shiny red head and thorax. Length 4 mm. to 7.8 mm. In *Languria mozardi*, as distinguished from other species of the genus, the antennæ are black, with the club five-segmented; the legs are red, with the outer half of the femur black and the tibiæ and tarsi often more or less dusky; last three abdominal segments black, the abdomen otherwise red; elytra rounded at apices, not sinuate, punctate-striate with the interspaces impunctate; scutellum red; head and thorax sparsely punctate.



FIG. 23.

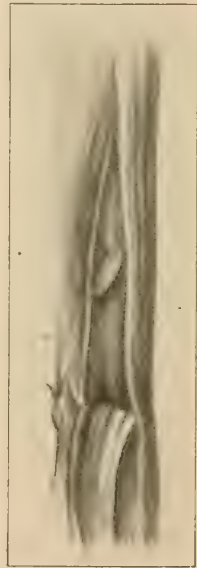


FIG. 24.

Clover Stem-borer, *Languria mozardi*: Fig. 23, beetle, greatly enlarged; Fig. 24, egg, in natural position, four times natural length.

The egg (Fig. 24) is translucent cream-yellow, paler at each end, elliptico-cylindrical and slightly curving, with one end slightly more tapering than the other. One specimen was 1.5 mm. long and 0.3 mm. broad; another, 1.9 mm. by 0.5 mm.

The larva (Fig. 25) is slender, subcylindrical, 8 mm. long and 0.9 mm. wide when full grown, and light yellow, with a pair of brown curving anal hooks. The thoracic legs are well developed and there is a single anal proleg. Comstock gives other details. At birth the larva is 2 mm. long; when four days old, 3 mm.; nine days, 5 mm.; full grown, as above.

The pupa (Fig. 26) is yellow, slender, has a large head, and is 6 mm. long.

Life History.—There is but one generation a year in this latitude. Here the species hibernates as a beetle. We have kept it alive over winter. It may also winter as a larva, as Chittenden found larvæ

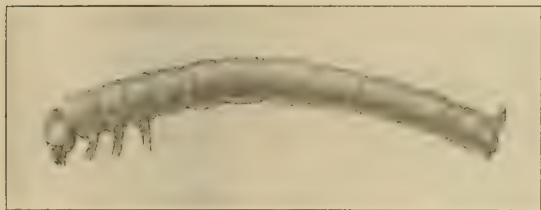


FIG. 25.



FIG. 26.

Clover Stem-borer, *Languria mozardi*: Fig. 25, larva; Fig. 26, pupa.
Both greatly enlarged.

remaining as such from November to April, in stems of ragweed. In late winter and early spring the beetles are to be found in red-clover fields under the rubbish on the ground. In spring they eat clover leaves to some extent, but do no conspicuous damage, as they are comparatively few. In May and June these beetles mate; by July 10, nearly all of them have died off; rarely does one of the wintered beetles survive into August. Young larvæ are common in the clover stems in the last week of June and early in July, for the most part; tho eggs are not uncommon early in July, and occur, rarely, as late as July 17. Larvæ of all ages are common in clover stems in July and thereafter; pupæ are most numerous about August 15; and the beetles of the new generation emerge from the first of August up to the middle of September, if not later. After the autumn frosts the beetles are to be found on the ground under the debris.

Such is the life history, in condensed form, for this insect in this part of Illinois. Some details of importance follow.

Eggs laid May 19 hatched May 24; those laid July 14 hatched July 17. The egg period was three days also in the case of eggs that hatched July 8, 9, and 10. Eggs were taken in large numbers in the field July 5, 6, and 7, at which time 20 percent of all the large clover stems examined contained each an egg. In one field 41 percent of the clover stems, taken at random, had egg pits July 6, with either eggs or small larvæ present.

Beetles that had hibernated, died in the insectary July 5, 9, and 26, after having been kept there with proper food, etc., since winter. By July 5 most of the beetles are gone from the fields; only a few stragglers continue to live, there being a conspicuous break between the last of the wintered beetles and the first beetles of the new generation. Larvæ, nearly or quite grown, and pupæ are common in old clover stems July 28 to August 7. About July 30 the larvæ are three times as numerous as the pupæ; but after the first week in August the latter exceed the former in number. The new beetles emerge mostly thruout August and during the first half of September. In the insectary they issued almost every day from August 3 to September 14, and one emerged September 20. Most of them have issued by August 26, however. At that date the burrows are almost all vacant, and the beetles are abroad in the field, feeding a little, seeking shelter at every cold spell, becoming more and more sluggish, and finally dormant. Not until spring does the reproductive instinct awaken.

Habits.—Oviposition occurs to some extent late in May and early in July, but for the most part in June, and has been witnessed in the daytime. The female gnaws a small pit on the stem of a plant, as Chittenden and others have observed. On clover stems these pits can be found easily. Unless freshly made, the pit is brown, in contrast to the green of the stem; a pit that is green is less than twenty-four hours old, and indicates, as a rule, the presence of an egg. The egg-pit is shallow, oval or round in outline, and not more than one sixteenth of an inch in length. In the center of the pit a minute linear or elliptical slit opens into the pith. Upon cutting open the stem, the egg is seen on the inner wall of the stem, often opposite the pit, but sometimes as far from it as four to six millimeters. The female makes the pit with her mandibles, then pushes the end of the abdomen thru the bottom of the pit and into the pith, these operations taking eight minutes in one instance and sixteen in another, as observed by E. O. G. Kelly. Sometimes a female gnaws out a pit without laying the egg. In red clover the eggs are laid singly, almost invariably, in my experience, rarely two being found together. In another plant (*Leucanthemum*), however, Mr. Girault saw at least fifteen eggs deposited in the same nidus (*Ent. News*, Vol. XVIII., pp. 366, 367).

The egg-pits occur on the main stem of a red clover plant anywhere from three to twenty inches from the ground, averaging ten inches, the old pits having been carried up more or less by the growth of the stem. Fresh pits, especially those on small stems, are usually not far from the ground.

The larva, feeding on the pith (Fig. 27), tunnels out the main stem for sometimes two feet. If two larvæ occupy the same stem their combined efforts may produce a burrow as long as thirty-two inches, extending from the main stem out into one of the larger branches. The largest larvæ and the pupæ (Fig. 28) are found usually at the lower end of the burrow, an inch or two from the ground, the pupa

with the head upward. The beetle (Fig. 29) after issuing from the pupa lingers in the burrow for a while, and then escapes by gnawing a round hole straight thru the wall of the stem. These exit openings are rather conspicuous.

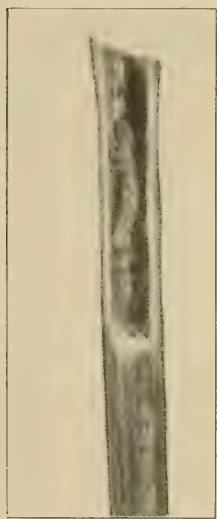


FIG. 27.

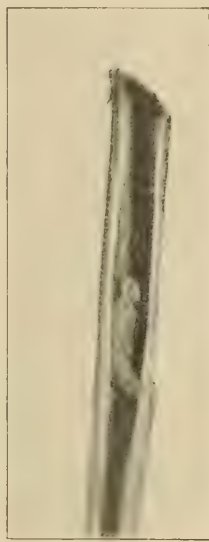


FIG. 28.

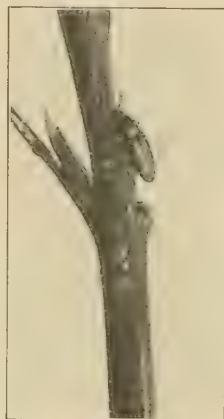


FIG. 29.

Clover Stem-borer, *Languria mozardi*: Fig. 27, larva, in clover stem; Fig. 28, pupa, in same,—both twice natural length; Fig. 29, beetle, on clover stem, slightly enlarged.

Natural Enemies.—Comstock mentioned two parasites that he found in the burrows of this stalk-borer: a small black chalcid, with a dark naked pupa; and a yellowish ichneumonid, the pupa of which is enclosed in a delicate white silken cocoon. C. M. Weed gave a figure and made brief mention of such a chalcid. I have found the chalcid—probably the same one—in considerable numbers by examining an immense number of stems. The egg of the parasite is found beside that of the stem-borer, and hatches a little later than the latter egg. The chalcid larva bites into the *Languria* larva and feeds upon it as an external parasite. Now and then the chalcid larva detaches itself from its host, but finds the latter again whenever necessary. The *Languria* larva dies; the parasite survives and becomes a naked pupa in the burrow, from which the adult emerges by cutting a minute round hole thru the wall of the stem.

Eggs, larvæ, and pupæ of the parasite were most frequent in the burrows July 6 to 8. The adult chalcids issued from July 11 to August 5,—most numerous, however, in the last week of July. August 26 nearly all the *Languria* burrows were empty, and the stems showed the exits of the host and those of the parasite.

An ichneumonid cocoon taken in a *Languria* burrow by me August 7 gave the adult August 11.

Neither of these species has been determined.

Control.—The clover stem-borer has not yet attracted much attention as an injurious insect. Such effects as it produces are not of the violent sort which attract notice. For a time I was in doubt as to whether the lodging of the plants was due in any degree to this insect; later, I found that affected stems do not lodge until they get large, but then fall sooner than unaffected stems.

Every year the farmer unknowingly kills off large numbers of these insects when he cuts his hay crop, whether he cuts it early or late, for in the latter part of June and thruout July in this latitude the great majority of the insects are inside the clover stems as larvæ or pupæ. The old beetles from the previous year are practically gone by July 5, and the new beetles do not issue from the stems until about the first of August. If the cutting of the hay crop is neglected, however, and left far into July, much of the clover will be flat on the ground from the work of this insect. I had this tested on the university farm, and when the clover was cut, heard, from the man who mowed the field, certain appropriate comments upon the amount of clover which had lodged.

If the red clover is cut when it should be—to make the best fodder—only about three stems in one hundred of the new growth will show the insect. To find many larvæ in July and early August one has to search in uncut field-clover, or in clover growing wild on the border of a field or by the side of the road or the railroad track. The practice of mowing and destroying volunteer clover is well worth the little time that it takes.

Languria mozardi Latr.

- 1880. Comstock, J. H.—Rep. [U. S.] Comm. Agr., 1879, pp. 199, 200.
- 1881. Lintner, J. A.—Fortieth Rep. N. Y. State Agr. Soc., 1880, pp. 18-20.
- 1890. Weed, C. M.—Amer. Nat., Vol. XXIV., p. 867.
- Weed, C. M.—Bull. Ohio Agr. Exper. Sta., Sec. Ser., Vol. III., No. 8, pp. 235-238.
- Chittenden, F. H.—Insect Life, Vol. II., pp. 346, 347.

CLOVER SITONES

Sitones flavescens All.

This small brown curculio eats the leaves of clovers and alfalfa, and its white footless grubs feed at the crown or at the roots of the same plants. It has rarely been reported as injurious in this country, but needs to be watched, nevertheless.

The species is abundant in the Atlantic states, especially near the seashore, is on record from Indiana, Illinois, Iowa, and Minnesota, and doubtless has a much wider distribution. Everything indicates that it came from Europe, where this and other species of the genus are injurious to clover and lucerne (alfalfa).

Food Plants and Injuries.—White clover, alsike, red clover, and alfalfa are known to be eaten freely by this insect. In Europe another food plant is the grass *Poa annua*. Webster found a strong preference for white clover and alsike over red clover in Indiana. Osborn and Gossard found red clover to be eaten readily in Iowa. Here in Illinois red clover is commonly eaten, but white clover shows rather more of the injury. Alfalfa is also eaten to some extent. The beetles eat at the edges of the leaves, and the larvæ feed at the roots or the bases of the stems.

The leaves are bitten out in a characteristic manner, on account of the methodical feeding habits of the beetle. On an expanded leaflet the beetle eats inward from the margin, making a small hemispherical or U-shaped gap. The symmetrical injury, shown in Figure 30, is, however, frequent, as the beetle often, if not usually, selects a young tender leaflet that is still folded in halves along the midrib, and notches out both margins at once; or it may bite out a hemispherical notch at the midrib, resulting in a round hole when the leaflet opens. When



FIG. 30.—Leaves of white clover showing characteristic injury by beetle of *Sitones flavescens*. Natural size.

all three of the folded leaflets are as yet side by side, the beetle at one operation produces the effect shown in the leaf at the left in Figure 30. A single notch constitutes a meal, whether the beetle happens to eat one thickness of the leaf or six.

The youngest larvæ work at the bases of the stems or the bases of the roots, tho most of the injury by them is done on the roots. A few of these larvæ, biting out the roots near the crown, can cause a plant to wilt, even tho no other insect is present.

Aside from the serious injury done to white clover and the attacks upon alsike in Indiana in 1885, as reported by Webster, this species has not put itself on record as an injurious insect in this



FIG. 31.—*Sitones flavescens*. Greatly enlarged.

country. In Europe, however, it has now and then shown what it is capable of doing in the way of damage.

Stages.—The beetle (Fig. 31) is a small dark brown or rusty brown curculio, 5.5 mm. in length, with the beak short and broad. It is distinguished from other species of the same genus by the absence of erect setæ on the interspaces of the elytra, and by its minute, narrow, hairlike scales. On fresh specimens the pronotum shows a pale median dorsal line and a pale stripe on each side, the lateral stripes being continued forward on the head, above the eyes, and along the beak; and also backward on the elytra for a short distance.

In the genus *Sitones*, of which we have several species that are potentially injurious, the mandibles are stout, convex on the outside, and roughly punctured; and the antennal grooves extend forward to the bases of the mandibles,—not to mention other characters given by Le Conte and Horn, and also by Casey. As in other *Curculionidæ*, the male has one more "dorsal segment" than the female, owing to the division of the pygidium into two segments.

The egg is subspherical, yellowish white at first, turning greenish, and becoming black in two or three days. The diameter is nearly 0.4 mm., tho the egg is a trifle longer than broad.

The larva, 5 mm. long when full grown, is a stout, yellowish white, footless grub. The head is small and yellowish brown, with whitish lines. Body segments a little larger than the head; the second and the third a little larger than the first. The legs are represented by fleshy double tubercles. The abdominal segments gradually decrease in size and bear longer hairs than the thorax, these being longest on the small ninth segment, which terminates in a short, stout, truncate pseudopod.

The larvæ assume a hooklike position, as mentioned by Webster, the head and thorax making almost a right angle with the abdomen.

The pupa, 5 mm. in length, is pale yellowish, bearing hairs, spinules, and tubercles. The abdomen gradually diminishes in size, and the segments bear a few short reddish spinules, transversely arranged: the ninth segment has also two long, slender, converging lateral spines, whitish basally and reddish apically, and toothed near the middle. The pupa and the larva have been described in minute detail by Xamheu.

Life History.—Scarcely anything on the life history of this species has appeared in our literature since Webster's useful article of twenty years ago. In central Illinois the general course of the life history is markedly like that of the clover leaf-weevil. There is one generation each year. The beetles live thru summer and autumn, and try to hibernate. The eggs are not laid until late in the season, but they hatch in the same season and the little larvæ hibernate.

March 23 I saw the characteristic signs of the beetle on one red clover leaf, recently expanded, and again March 28, on white clover. The beetles are rare, however, in spring, and the earliest record that

I have of actually finding the beetle is June 19. This may have been—and probably was—one of the new brood, the adults of which are not uncommon in the last week of June and become common by the middle of July. They emerge over a considerable period, as our records show, our dates of emergence being July 10 and 16, and August 20 and 25. The pupal period is two to three weeks. Thru July, August, and September the beetles are common in the field, where we have found them as late as October 8, 14, and 31, and November 25; and indoors, they may be kept alive far into the winter and doubtless until spring. Like the clover leaf-weevil, these other curculios feed for a long time before mating and laying eggs. Dates of coition are July 1 (exceptionally early); August 26, 30, and 31; September 1, 8, 10, 15, and 27; October 10, 18, and 25; and November 14. All these records except those of September 8 and 10 were made in the insectary (unheated but yet affording some protection from frost), and out-of-doors mating and oviposition would not occur for quite so long a time. Two to ten days elapse between coition and egg-laying. In the field most of the eggs are laid in September. Indoors we have found them to have been laid September 12, 14, 15, 19, 20, 22, 25, 26, 27, and 29; October 23 and 27; and November 1, 2, 3, 4, 5, 10, 14, 16, 17, and 23. For several years we have kept the beetles in abundance under daily observation thruout their long lifetime, without getting other dates of oviposition than these. A single female lays her eggs at irregular intervals extending over several weeks. Thus a female which copulated October 25 laid eggs October 27, November 2, 10, 17, and 24. The egg period varies, even under conditions apparently the same, and ranges from 13 to 32 days. Hatching occurred in the insectary from October 17 to November 29, mostly in November, and most of it before winter. Not a few eggs, however, failed to hatch in autumn, and did not hatch the following spring, when they were evidently dead. There remains, nevertheless, the possibility that some eggs survive the winter.

The species winters chiefly as a young larva, but occasionally survives as a beetle in this region.

Webster dug up frozen clover sod on December 9, at Lafayette, Ind., and found therein, after thawing it out, *Sitones* larvæ, some of them 1 mm. long, most of them under 2.5 mm. in length, and two full grown and in earthen cells. He found also two beetles, but no pupæ. One of the adults was still alive February 18. April 13 he found in the field, larvæ (less numerous than in December, and in about the same stage of growth), no pupæ, and two beetles, which died soon afterward. May 25 he obtained larvæ (less numerous than in April, but now nearly or quite full-grown) and pupæ, and a single adult, which died May 30. These beetles laid no eggs. June 14 he found several adults. I regard these as belonging to the new brood.

Webster's account serves almost exactly for the species as it occurs here in Urbana. He found, however, that eggs laid October 17 and 25 hatched in about 48 hours at a temperature of 65° F.—a much

shorter period than any that we have as yet found. He notes eggs as being laid as soon as August 7, and copulation as occurring in the field as late as November 12.

Habits.—One or two beetles manage to live over winter, and even to eat a little in early spring. Probably they issued late in the previous season and had enough vitality to carry them over to the next season. I do not believe that such beetles lay any eggs in spring, however, in this locality.

When the larvæ emerge from the egg in autumn they feed on tender green tissue down where the stems join, avoiding the light and biting out little crevices, in which they lie. As it gets colder, they go down deeper and reach the roots. The larger larvæ and the pupæ are found on the roots, and part of the eggs are laid there, some of the female beetles, after copulation, burrowing down along the roots. Other females, in the breeding-cage, drop their eggs promiscuously.

The beetles, like the larvæ, avoid bright sunlight. Most of them feed by night. Some feed, to be sure, in the daytime when the sky is overcast, or even in bright daylight on a shaded portion of a plant. To find many of the beetles during the day, however, one must scrape away the rubbish on the ground near clover plants that show the characteristic work of the insect. The beetles when exposed to the light are quick to recover their wits, and to hurry off to another sheltered situation.

The beetle when engaged in feeding stands astride upon the edge of a leaflet and stays in the same spot, swinging its head and thorax up and down as it eats, and biting out a rounded gap always of about the same form and size. The beetles are alert when feeding, and drop to the ground without hesitation when approached incautiously. Indoors they will feed in the daytime if the light is not too strong.

Control.—No enemies of this species have been found up to the present. Should it become destructive it would be hard to deal with. The cutting of the hay crop has little or no effect upon the larvæ or the beetles; the former continue to feed on the roots, and the latter feed temporarily on the green stubble and attack the new leaves as soon as they appear. In a field of red clover cut July 1, I found the beetles and larvæ common July 15; on clover cut July 23 the new leaves showed considerable injury July 30.

Fortunately it is not necessary as yet to prescribe remedies for the attacks of this weevil.

Other Species of Sitones.—In Europe several species of *Sitones* are injurious to clovers and allied plants. In America we have at least four of the European species, namely, *flavescens*, *tibialis*, *hispidulus*, and *lineellus*. *Tibialis* is of no economic importance here. *Hispidulus*, according to Schwarz, is a recent importation. It was first noticed in 1876 in New Jersey, and subsequently in New York, Maryland, and Pennsylvania. The species is injurious in the old country and may become a pest here. Schwarz found it to be abundant in 1889 in Washington, D. C., feeding on red clover.

Lincellus is another potential pest, having injured clover and alfalfa in Europe, tho it is not common here as yet. In Urbana, it occurs occasionally in red clover fields, and the beetle eats the leaves of that plant. A female taken November 26, 1907, by Mr. R. D. Glasgow, a student at the University of Illinois, was kept alive on clover leaves for a long time, under daily observation, and laid eggs, eight being found November 27, and 10 on November 30. These are oval, pale translucent yellow when laid, becoming jet-black; surface minutely granulate; length, 0.5 mm.; breadth, 0.38 mm. Five of the eggs found November 27, and laid not before November 26, hatched December 16. The larva at hatching is white, stout, and footless, with a black head, and its length is 0.82 mm. The body is wrinkled to such an extent as to obscure the segmentation. The larva is like that of *flavescens*, and bends the head and thorax over in the same manner. These larvæ fed readily on red clover, digging into the bases of roots or stems.

To these few but new notes on the life history is added a sketch of the newly born larva of *lincellus* (Fig. 32).



FIG. 32.—Larva of *Sitones lineellus* at hatching. Greatly enlarged.

Sitones flavescens All.

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- 1890. Schwarz, E. A.—Proc. Ent. Soc. Washington, Vol. I., pp. 248–250.
- 1891. Osborn, H., and Gossard, H. A.—Bull. No. 14, Iowa Agr. Exper. Sta., pp. 177, 178.
- 1896. Xamheu.—Mœurs et Métam. d'Insectes, Mém. 5, pp. 130–133; Extr., Ann. Soc. Linn. Lyon, Vol. XLIII., pp. 152–155.

CLOVER-ROOT MEALY BUG

Pseudococcus trifolii Forbes
(*Coccus trifolii*, *Dactylopius trifolii*)

This root-feeding mealy bug must in future be counted among the insects that kill clover plants. Its capacity in this respect has been overlooked, few entomologists having paid any attention to this inconspicuous subterranean species.

The insect occurs near the crown of the plant, as a plump oval sluggish mealy bug, with more or less of a white coating. It sucks the sap of the root by means of a minute beak. Legs and antennæ

are present, but are very small. Almost always the bugs are found in groups composed of individuals of various sizes, the largest being 2.5 mm. in length. Usually, also, these mealy bugs are accompanied by ants.

As yet we know of the presence of this species in New York, Delaware, Illinois, Michigan, Iowa, and Kentucky only, but may safely assume that it occurs in many other states.

This coccid is common on both red and white clover, and has been reported from the sugar-beet by R. H. Pettit.

Tho these mealy bugs may be found in moderate numbers on the roots of plants that appear to be healthy, the easiest way to find them is to examine clover plants that are more or less wilted. Unaided by other insects, the mealy bug often kills the clover plant. At first a few leaves droop; then as these wilt and die other leaves droop, until finally all the leaves are dead. No new leaves come forth. With sufficient rain, however, the plant revives if not too far gone. On the other hand, drought intensifies the effect of this sap-sucking insect. Furthermore, the plant may suffer at the same time from the root-borer, the leaf-weevil or the clover-louse, or from disease, old age, poor soil, overpasturage, etc.

A certain proportion of the larvæ go from the roots to the leaves to feed, and may cause the leaves to turn yellow and to die.

The fact that the injury from this insect is not wide-spread is accounted for by the feeble ability of the wingless females to go from one place to another, and the habit of the somewhat more active larvæ to stay on the same plant. I have never found the species on first-year red clover, tho its occasional occurrence on such clover might be expected; the spread of the insect is very gradual; second-year clover is affected in a sporadic way, except in a few localities where the insect has obtained a foothold; and the worst injury is done to clover, either volunteer or cultivated, that has run for more than two years.

Stages.—The winter female was described by Forbes as follows: "The body is elliptical, broadly and equally rounded at both ends, nearly circular in transverse vertical section, distinctly segmented; surface covered with waxy bloom, smooth except for a few small hairs at the anal extremity. Feet, eyes, and antennæ minute. The body is .11 of an inch long, a little more than half as wide, and a little less than half as deep; the abdomen decidedly shorter than the head and thorax; the antennæ .006 of an inch long, their length less than the distance between their bases, obscurely seven-jointed [fig. 33, a]; the first joint as wide as long; the second a little shorter and much narrower than the first; the third and fourth a little smaller than the second and not distinctly divided; the fifth and sixth distinct, equal in length, and about equal to the first; the seventh long, cylindrical, equal to the two preceding, obtusely pointed at tip. Entire antenna minutely sparsely hairy under a high power. Eyes simple, consisting of a single ocellus and a black speck on the side of the head, directly behind the antenna, the third joint of which will about reach them.

"Legs .01 of an inch in length, each reaching about one half way to its fellow of the opposite side. Tarsus one-jointed, as long as the tibia, tapering regularly, terminating in a single stout curved claw; tibia and femur of about equal length; trochanter as long as the coxa. Legs very minutely sparsely hairy throughout. Rostrum very minute, in the form of a thick tubercle projecting downwards in front of the bases of the anterior legs, scarcely longer than wide, about half the length of the femur."

I may add, after a study of the types, that the bristle of each caudal tubercle (anal lobe) is subtended by a pair of conical projections (Fig. 34, a); the anal ring bears six long bristles; the tarsal digitules are four in number and knobbed, as in Figure 35; and the claw bears no teeth. The largest of the types is 2.5 mm. in length.

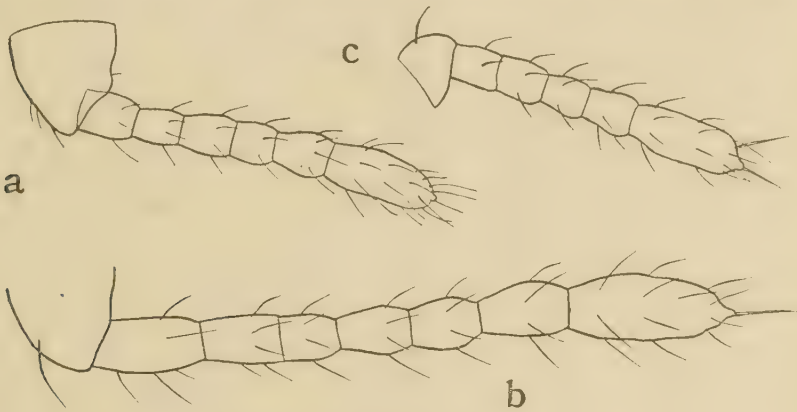


FIG. 33.—Antennæ of *Pseudococcus trifolii*: a, winter female; b, summer female; c, larva. Greatly enlarged.

The summer female has been described by G. C. Davis and by R. H. Pettit. The latter author writes: "The adult female measures a little more than two millimeters in length, is reddish brown, in color, covered with a coating of waxy or mealy secretion. The legs are dirty yellow in color. From the sides project 15 to 17 (usually 17) waxy processes, forming a fringe around the body in the usual manner, with the shortest filaments near the head, and those near the tail considerably longer, sometimes one third as long as the body. The antennæ [Fig. 33, b] are eight-jointed; joint one is swollen, as broad as long; two and three are subequal, each about as long as one; four, five, six and seven subequal, a little over half as long as two or three; eight usually a little longer than five and six joined. There is considerable variation in four, it is sometimes smaller than five, six or seven, and sometimes slightly larger. The legs are dirty yellow, in length the tarsus of hind leg is slightly more than half the tibia, which about equals the femur. Digitules four; the two superior long and slender, the two inferior shorter and more stout. (The digitules were

not distinct, but appeared as described.) Anal tubercles [Fig. 34, b] not prominent, with a mass of small glandular spots, and bearing one

long hair, with sometimes several smaller ones. Among the glandular spots are placed two conical projections or processes on each tubercle. These processes are from two to three times as long as broad at the base. Derm dotted with small round glandular spots. Back, near the caudal margin, spotted with larger round gland-

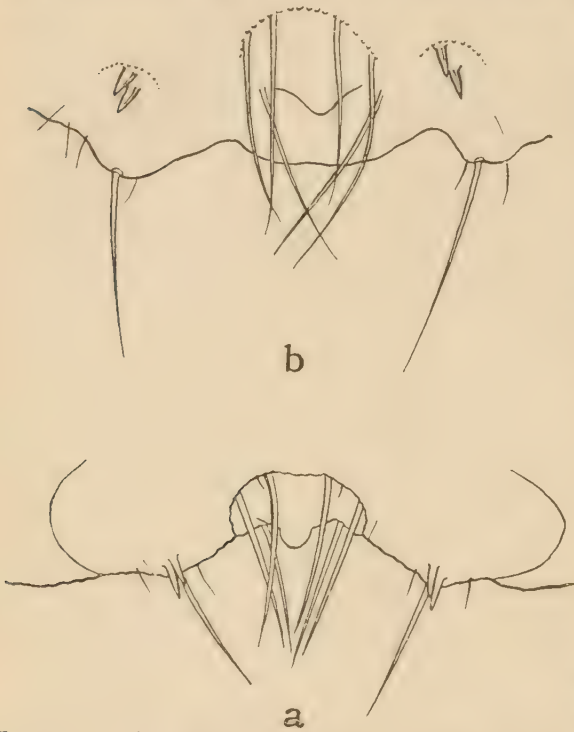


FIG. 34.—Caudal region of *Pseudococcus trifolii*: a, winter female; b, summer female. Greatly enlarged.

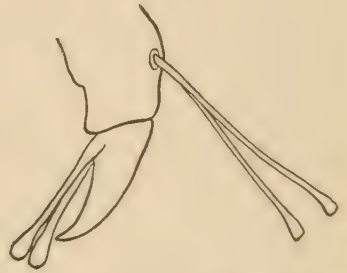


FIG. 35.—Foot of *Pseudococcus trifolii*. Greatly enlarged.

ular spots." Digitules and claws as described and figured by the writer.

The larvæ derived from the winter females are from 0.69 mm. to 0.78 mm. long and half as broad as long at birth, and are elliptical and flat, looking much like scale insects. The antennæ are six-segmented (Fig. 33. c). The minute structures of the caudal region are essentially like those of the adult females, as in Figure 34.

The male, which G. C. Davis described, is a minute two-winged insect, with two long white tail-filaments, two pairs of eyes, delicate milky-white wings, and the body thinly covered with a white powder. The head, thorax, and first two antennal segments are of a deeper red than the abdomen, legs, and remaining antennal segments. The eyes are dark reddish brown. A mouth is not evident.

The egg is elongate oval, 0.34 mm. long and 0.17 mm. broad, translucent orange-yellow at first, becoming brownish yellow later, and with a smooth surface. The egg-mass is surrounded by the cottony secretion of the mother.

The winter females that I examined all had seven antennal segments; the grown larvæ, six; the full-grown summer females, eight;

partly grown larvæ show the stages of transition from six to eight segments. In young larvæ the division between segments two and three is frequently obscure; in the large females the suture between segments two and three, or three and four, is obscure.

Mr. Pettit, who studied summer females, intimated that the winter specimens from which the original description was made were male pupæ. A study of the types, however, has shown me that they are females, some of them being full grown, tho they resemble the male pupæ to the extent of having only seven antennal segments.

The necessity for using the name *Pseudococcus* for the genus formerly called *Dactylopius* has been explained by Cockerell (Ann. Mag. Nat. Hist., Ser. 7, Vol. IX., 1902, pp. 453, 454).

Life History.—The first account of this coccid was given by Dr. Forbes, who found the species on the roots of white clover May 3, at Normal, Ill. He found that the coccids "were protected by a small yellow ant, *Lasius flavus*, in whose nests they occurred, and were carried away by them like plant-lice when the nest was exposed."

The general course of the life history has been made known by G. C. Davis from his studies in Michigan. He found the coccids abundant in clover fields April 27, and attended by *Lasius niger*. When the nests of the ant were opened, the ants carried away these coccids to another location. These were winter females. Davis put some of them on potted clover and obtained young, the first appearing May 15; these "gathered under the mother bug or collected in the flocculent mass back of her that she had secreted while producing them. They were of a light, translucent flesh-color, and much flatter than the mother."

The oviparous female makes a nest of waxy threads and places therein 75 to 300 eggs. "At first she is large and plump, but, as the pile of eggs increases, she decreases in size until at last there is nothing left of her but a little dry wrinkled piece of lifeless skin, and a mass of eggs back of her that will measure two or three times as much as she did a short time before. The time required for the eggs to hatch, and the young mealy bugs to reach maturity, is only about six or seven weeks."

The mealy bugs, tho numerous in the latter part of summer, disappear in the fall, according to Davis, who failed to find them in any stage October 15 where only a few weeks before they had been plentiful. He suggested that they had changed to the winter form and had been carried off by the ants.

Davis found also that the male, when about half or a third the size of the full-grown female, crawls up to some part of the plant above ground, spins a fluffy cocoon, and comes out, in less than a week, as a winged adult.

In Urbana, the winter females of various sizes occur on the roots of clover, attended by ants, in early spring. Our earliest dates are March 24 and 26, but the females could doubtless be found thruout

the winter. Small winter females taken March 28 and placed on the roots of potted clover thrived until June 13, then disappeared.

Of the young brought forth on the roots by winter females, some stay on the roots, but multitudes at once climb the stem of the plant and fasten themselves by the beak to the under sides of the leaves. These oval, flat, green, scalelike larvæ may stay on the leaves for a month or a little longer, growing meanwhile, or may go to the ground sooner than that. One larva taken in the field May 25 and transferred to potted clover stayed on the leaves until June 5, then disappeared, to reappear June 9 down on the stem near the ground; there it remained until June 27, when it moulted; July 5 it had disappeared for good.

The young larvæ on the leaves I found to be common June 24, July 5, and July 8; those of the first two dates were newly born and had not moulted. Larvæ on leaves June 24 were transferred to the roots July 30, where they thrived thruout August.

These individuals above ground wander about as they get older, and at length go to the ground, some dropping off the plant, perhaps by accident, while others creep down the stem to the roots. This migratory habit of the larvæ and their development on the leaves have not heretofore been noted apparently. Very likely it will be found that these aerial females are fertilized by the winged males.

While these individuals are feeding on the leaves there are others of all sizes feeding in groups on the roots; in fact, the root-feeding forms can probably be found every day in the year. The number of generations has not been made out.

No eggs have been found in spring, and in our experience they are not laid until late in the season. Our dates for oviposition in root-cages are August 31, September 1, 2, 3, 5, and October 31. We have taken eggs in the field August 31 and September 15 and 27. The eggs always hatched before winter, the egg period being either 9 or 10 days in September, and 19 days for the eggs laid October 31. The dates of hatching that we have noted are September 1, 2, 5, 10, 11, 12, 15, 18, 29, and November 19. The young from these eggs we have carried far into the winter on clover roots, and regard them as being the winter females, which are to attain their full growth in spring.

Habits.—The summer females wander about considerably on the roots and often go above ground, to resume feeding at the base of the plant in some crevice protected from the light, where they often lay eggs.

As met with in the field, this mealy bug is almost always accompanied by ants, which have made their nest about the roots of the clover plant. The species of ants found here, in this relation, are *Lasius flavus* DeG., as mentioned by Forbes, and three other common species: *Lasius niger americanus* Mayr, *Lasius interjectus* Mayr, and *Myrmica scabrinodis lobicornis* Nyl.

This coccid can get along very well without the ants, however—unlike the corn root-louse. In a root-cage the ants sometimes desert the coccids, but the latter continue to feed and to produce eggs and young as tho nothing had happened. In this instance the ants derive most of the benefit from the partnership. When an ant finds one of these mealy bugs on the ground or on the base of a plant, the ant picks it up in its jaws, carries it down under ground, and deposits it somewhere on the roots, usually not far from the base. If there are eggs with the female, the ants carry these down also and put them on rootlets.

When these coccids with ants and their cocoons are put on the surface of the soil in a root-cage, the ants begin by burrowing down along the roots. Then they carry down the coccids and the cocoons. The former they place on the roots, but the latter they carry down deeper to special chambers. If there are eggs of the coccid, the ants show many attentions to them—touching them often with the tips of the antennæ, carrying them from place to place, and often cleaning them with the mouth—in short, treating them as they do their own eggs. The coccids are left much to themselves, but occasionally an ant may be seen eating the white waxy secretion of the body of the female. Mr. E. O. G. Kelly says that this secretion is eaten only when it is newly made and fresh. Much of it is left by the ants and is used by the female to cover her eggs.

In the field the coccid is now and then seen above ground at the base of a plant when no ants are present. Occasionally, also, the coccids are found working on the roots without ants, there being either no sign of ants or else a nest that appears to be deserted.

This coccid spreads very slowly, as has been said. Newly born larvæ climb the stem to the leaves, but seem not to leave the plant to any great extent, tho a few may be found on such neighboring plants as are easily accessible. The summer females frequently go above ground and wander about a little, tho they are sluggish. Probably the species is spread by ants faster and farther than by any other means.

No natural enemies of this mealy bug are as yet known.

Up to the present the species has been of only minor economic importance.

Pseudococcus trifolii Forbes.

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EXPLANATION OF PLATE II.

- FIG. 1 to 3.—Clover Seed-midge, *Dasynura leguminicola*: Fig. 1, larva, ventral aspect; 2, sternal spatula; 3, female midge. All greatly enlarged.
- FIG. 4 to 8.—Clover Leaf-midge, *Dasynura trifolii*: Fig. 4, galls on white clover, also larvæ and cocoons, natural size; 5, eggs; 6, larva, dorsal aspect; 7, sternal spatula; 8, female midge. Fig. 5 to 8 are greatly enlarged.
- FIG. 9 to 11.—Clover Seed-caterpillar, *Enarmonia interstinctana*: Fig. 9, larva at work in head of red clover, natural size; 10, larva, enlarged; 11, moth, enlarged.



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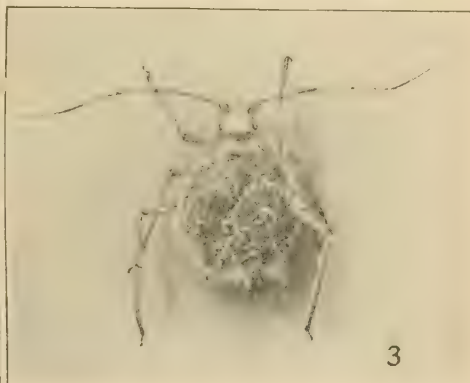


PLATE III.

FIG. 1 to 4.—Clover-louse, *Macrosiphum pisi*: Fig. 1, winged viviparous female; 2, wingless viviparous female; 3, aphid attacked by fungus, *Empusa aphidis*; 4, empty skin after emergence of parasite—*Aphidius*.

FIG. 5 and 6.—Clover Callipterus, *C. trifolii*: Fig. 5, wingless viviparous female; 6, winged viviparous female.

ERRATA

Page 1, line 17, for *alienus* read *niger*.

Page 34, line 11, beginning with *One* dele as far as comma, substituting
The small yellow ant (*Solenopsis molesta*).

Page 37, last line, for *red house-ant* read *small yellow ant*.

Page 38, first line, for *debilis* read *molesta*.

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TWENTY-SIXTH REPORT

OF THE

STATE ENTOMOLOGIST

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ON THE

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OF THE

STATE OF ILLINOIS

FIFTEENTH REPORT OF STEPHEN A. FORBES

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SOME IMPORTANT INSECTS OF ILLINOIS SHADE TREES AND SHRUBS

BY STEPHEN A. FORBES, STATE ENTOMOLOGIST

The protection of the shade trees and ornamental shrubs of Illinois against insects has been for several years a problem of rapidly increasing importance. Many of our most desirable trees and shrubs are liable to slow destruction by obscure insect pests understood little if at all by those immediately concerned. Trees which have grown for years, becoming more attractive, more valuable, and more highly valued year by year, begin to weaken and decay, the owner does not know why. This is often due to borers or to scale insects, the presence of which has not been detected or suspected, but whose injuries might have been prevented if the facts had been known in time. More sudden losses are frequently caused by overwhelming attacks of leaf-eating insects which, altho conspicuous, are not dealt with because proper measures of procedure are not known. Observations and experiments upon this subject have been for several years a prominent part of the work of the office. Beginning in 1898, repeated careful examinations have been made of the trees and shrubs of the parks and boulevards of Chicago, and this work has been extended from time to time to other cities and towns thruout the state. With the establishment of a field assistant in Chicago in 1907, the subject received more continuous attention at the hands, first, of Mr. H. E. Hodgkiss and, later, of Mr. John J. Davis, the latter of whom especially has made many studies of the life histories of species previously but little known, and has added a mass of details to our knowledge of the subject in all its parts.

The general subject is still under investigation, and will be in due time reported upon in a much fuller and more elaborate article, but the present brief preliminary paper has been prepared in the hope that it may be found of immediate practical use to municipal authorities in control of parks, boulevards, and streets, to town improvement societies, and to owners of lawns and other private premises the appearance of which they are striving to improve by the use of trees and shrubs.

THE CATALPA SPHINX
(*Ceratomia catalpæ* Bdv.)

One of the most destructive of the few insects to which the catalpa tree is subject is a large showy caterpillar known as the catalpa sphinx (Fig. 1). It is a southern insect, and has not been found in this state north of Clay and Richland counties, altho it has



Fig. 1. Catalpa Sphinx (*Ceratomia catalpæ*): a, egg mass; b, newly hatched larvæ; c d, larvæ one-third grown and one joint showing its dorsal pattern; e, f, g, h, i, mature larvæ, variously marked, and single joints showing dorsal patterns; j, pupa; k, moth; l, egg, enlarged; others all slightly less than natural size. (Ohio Experiment Station.)

extended up the Atlantic coast as far as New Jersey. It is likely to appear suddenly in large numbers upon single trees, stripping them completely.

The full-grown caterpillar (Fig. 1, *c*, *f*, *h*) is rather strongly marked, with a broad velvety black stripe on the back and sulphur-yellow sides spotted with black, while the under side of the body is pale green. It is unusually variable in color, however, there being both light and dark forms. It is from two and a fourth to three inches long, and has a hornlike appendage projecting from the hinder end of the back. The young caterpillars (Fig. 1, *c*) are pale yellow and spotted with black. There are probably but two generations in Illinois. The caterpillars leave the trees and go into the ground to pupate (Fig. 2).

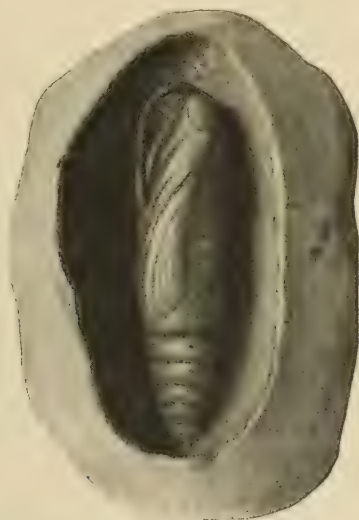


Fig. 2. *Catalpa Sphinx*, *Ceratomia catalpæ*, pupa in cell in earth.

The parent insect is a large heavy-bodied moth (Fig. 1, *k*) with strong, narrow, brownish-gray wings, with obscure lines and spots of black. The eggs (Fig. 1, *a*) are laid in masses on the leaves, sometimes as many as a thousand in a bunch, and the young, on hatching, feed at first in companies—a fact which makes it easy to destroy them if their presence is detected early, by picking off or spraying the infested leaves. A general spraying of a tree with arsenate of lead or Paris green will destroy the caterpillars at any time. Professor H. Garman, of Kentucky, says that the nearly grown worms can be shaken or jarred down from most catalpa trees and readily destroyed by hand.

THE FALL WEB-WORM
(*Hyphantria textor* Harris)

The fall web-worm is the only common Illinois insect which makes a large conspicuous web in late summer and in fall, inclosing a considerable number of the leaves and twigs of a branch, together



Fig. 3. Fall Web-worms, *Hyphantria textor*, and their web, on apple-tree.
(New Hampshire Experiment Station)

with a colony of caterpillars which feed under its protection (Fig. 3). It is unfortunately often called in Illinois the tent caterpillar, but the latter name is properly applied only to a caterpillar, not often seen in this state, which makes a small compact web in the forks of a branch in spring, which it uses only for protection while not eating.

The web-worm is an almost universal feeder and has been found on about a hundred and twenty species of fruit, shade, and ornamental trees, upon the leaves of which it feeds. It is one of the most annoying pests of the tree grower, its numerous large webs, enclosing brown, skeletonized leaves, making the tree very unsightly, and the injury done, as it spreads from branch to branch, often being considerable. While the caterpillars are growing they do not wander from their common web, but enlarge this to cover fresh leaves as fast as those within it are devoured. When they have nearly completed their growth, however, they scatter far and wide, running briskly about when disturbed, and feeding on almost

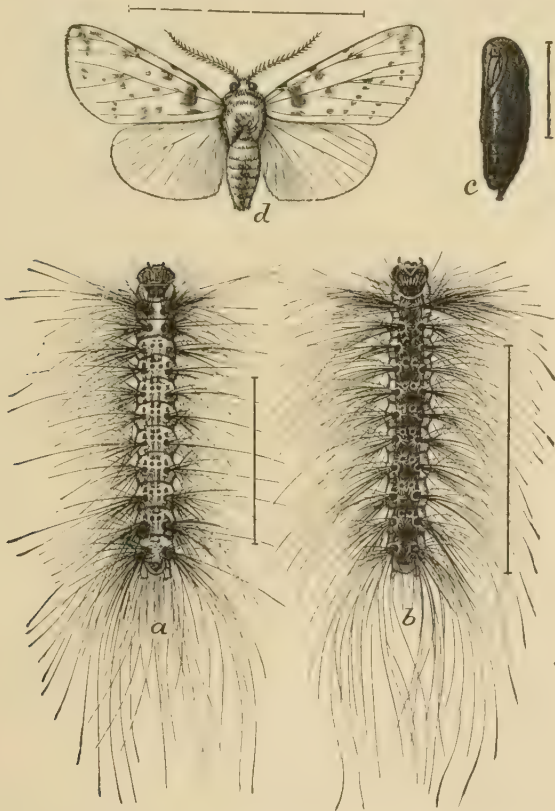


Fig. 4. Fall Web-worm, *Hyphantria textor*: a, b, larvæ, light and dark varieties; c, pupa; d, moth, spotted variety. All slightly enlarged. (New Hampshire Experiment Station.)

every green thing they find. At this time they become, when very abundant, an extremely destructive and annoying pest.

They are about an inch long when full grown, varying from pale yellow or grayish to a dark bluish-black hue. (Fig. 4, *a, b*.) The body is covered with long straight hairs grouped in tufts rising from small black or orange-yellow tubercles, of which there are a number on each segment. When mature, the caterpillars go to the ground, into which they burrow a short distance, or they creep under shelter above ground, where they form slight cocoons of silken web interwoven with the hairs from their bodies. Within these they change to dark brown pupæ (Fig. 4, *c*), and in this condition they pass the winter. The moths emerge in spring and lay their eggs in broad patches of several hundred each, on the under side of the leaves near the end of a branch, late in May and early in June. The adult insect is usually pure white, but is sometimes white spotted with black. There are either one or two broods of this species, according to the latitude, two in southern and central Illinois and probably but one in the northern part of the state.

The simplest and most effective method of controlling these insects is to destroy their webs, and the caterpillars within them, either by cutting off the twigs which bear them and crushing or burning them immediately, or by burning the webs on the tree. A bundle of rags or a few corn-cobs, or even a porous brick, wired to the end of a pole long enough to reach the nest and saturated with kerosene, makes a good torch for the purpose. Care must be taken, however, not to injure the tree, and to destroy the scattering worms which may drop from the nest without being killed. Where the infestation is too general to make this method convenient, or where the webs are so high in the trees that they can not be readily reached, a spray of arsenate of lead will eventually kill the web-worms as they extend their webs over the poisoned foliage. Paris green may be used instead, but the lead arsenate is to be preferred because, being much more adhesive, it lasts longer on the tree. This method is most effective when the caterpillars are young, since they are then extending their webs rapidly and are likely to be more promptly poisoned than when they are virtually full grown.

THE YELLOW POPLAR - CATERPILLAR

(*Apatela populi* Riley)

The prominence of the Carolina poplar as a city tree, especially in situations where it is difficult to find any other which can endure the conditions prevailing, makes it the duty of the Entomologist to discuss the insect enemies of even this rather inferior variety.

Among those which have recently been found most injurious to the poplar is a large and rather handsome, light yellow or pale green, very hairy caterpillar (Fig. 5), most easily known by five long pencil-like tufts of black hairs rising one behind the other on the middle line of the back, the first on the fourth segment of the body and the fifth on the last. This caterpillar was particularly injurious to poplars and considerably so to willows in Chicago in 1909. It has been noticed by us also in Peoria, Danville, and East St. Louis. It feeds on the leaves in midsummer and again in fall, there being two generations in a year. It sometimes completely

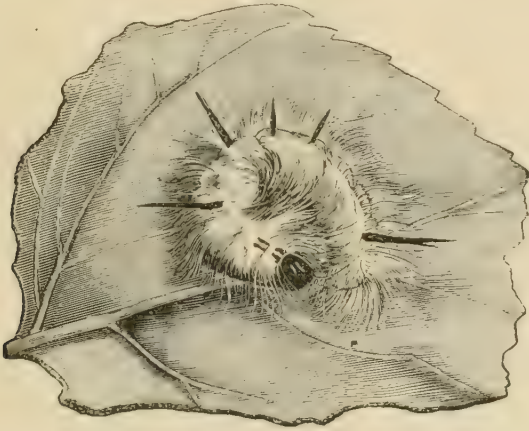


Fig. 5. The Yellow Poplar-Caterpillar, *Apatela populi*, natural size.

strips a tree, rendering it unsightly and putting it in poor condition to withstand unfavorable conditions or to resist the attacks of more destructive insects.

The caterpillar when full grown is about an inch and a half long, the skin yellowish-green, and the long, soft, drooping hairs yellow. The pencil-like tufts referred to rise from the fourth, sixth, seventh, and eleventh segments, those on the seventh and eighth being the smallest. The head is shining black and there are black spots on the top of segments one and two. The young are almost white, and the black tufts of hairs are shorter, but still conspicuous. The caterpillar is of a sluggish habit, and when at rest it commonly lies curled up, with the ends of the body together. When full grown it spins a loose, pale yellow cocoon of silk interwoven with its own hairs. This is generally placed in a crevice of the bark, under the edge of a fence board, or in some similar sheltered place. The winter is passed in this chrysalis stage, from which a large, pale gray moth emerges the following May.

The caterpillars are most easily destroyed when young, for they do not at first scatter from the branch upon which they were born.

Later they can readily be collected singly by hand from trees of small size, or they may be poisoned, like most of the leaf feeders, by spraying with arsenicals when they are active on the tree.

THE WALNUT CATERPILLAR

(*Datana integerrima* G. & R.)

The most annoying insect enemy of the walnut is a blackish, somewhat striped, hairy caterpillar (Fig. 6), an inch and a half long when full grown, which eats the leaves during the latter part of the summer, often largely denuding the tree. It makes itself particularly offensive on lawns by dropping quantities of refuse from the tree and by crawling over walks and buildings when it comes down to go into the ground.

This caterpillar is readily distinguished by its loose coat of soft whitish hairs, and particularly by its habit of raising both ends of the body when at rest and throwing itself into this position and jerking sidewise when disturbed. It often attracts attention by collecting in masses upon the larger branches or the trunk of the tree preliminary to molting, piling up in this way two or three layers deep. When full grown it comes down the trunk to the ground, wanders about to a short distance and enters the earth an inch or two, changing there to a reddish-brown or blackish-brown chrysalis (Fig. 6, B). In this stage it winters, emerging the following summer, mainly in June and July, in the form of a buff-brown moth (Fig. 6, A) with darker bands across the fore wings. The females lay their eggs in clusters varying from seventy-five to a hundred, according to some observers, and from five hundred to twelve hundred, according to others, and the young hatching from these feed in dense clusters, completely devouring every leaf as they go. When all the leaves on one twig or branch are destroyed, they migrate to another, sometimes in a distant part of the tree. They lose their gregarious habit as they mature, and by the time they are full grown they scatter here and there over the greater part of the tree. There is but a single generation in a year.

Altho they are most frequently seen on the walnut, they are common on butternuts and hickories, and are a pest to the grower of the pecan. They have likewise been found on beech, oak, willow, honey-locust, apple, and thorn. Trees in the forest are not likely to suffer, but those on streets and lawns are sometimes so completely stripped by September that they stand almost as naked as in mid-winter, only the green nuts remaining on the branches.

This account of their habits is sufficient to suggest various available methods of destroying them. On trees small enough to be reached they can be readily killed while young by clipping off the

infested twigs on which the caterpillars are grouped in colonies. They are particularly exposed to attack as they assemble in masses for their later molts, when a light spray of kerosene will readily kill them. They are also susceptible to arsenical poisons sprayed

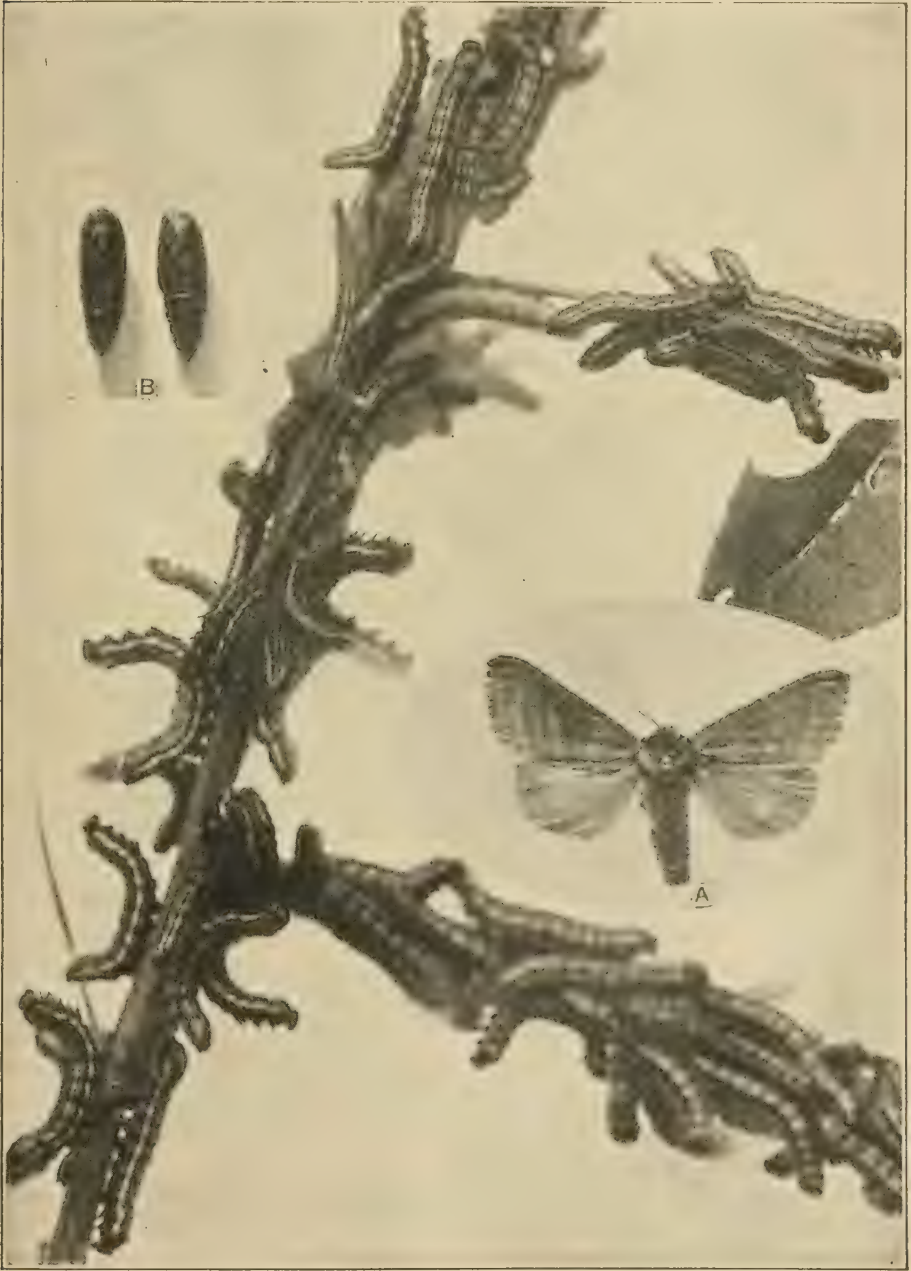


Fig. 6. Walnut Caterpillar, *Datana integerrima*: A, moth; B, pupæ. Natural size. (Kentucky Experiment Station.)

upon the leaves, but these must be used in unusual strength. We have found three pounds of arsenate of lead to fifty gallons of water sufficient to kill the full-grown caterpillars. On one occasion a tree nearly fifty feet high was effectively sprayed by the aid of a twenty-eight-foot ladder and a twelve-foot extension rod with a nozzle on the end, about twenty-five gallons of the spray being necessary for a thoro treatment. If these various measures have been neglected and the caterpillars have left the tree, they may still be disposed of in the pupa stage by digging up and working over the ground under the branches and for a little distance outside, to a depth of three or four inches.

THE WHITE-MARKED TUSSOCK-MOTH

(*Hemerocampa leucostigma* S. & A.)

The most destructive leaf-eater infesting shade trees in the larger cities of Illinois and especially in Chicago is the caterpillar of the white-marked tussock-moth. It often completely defoliates large trees, those most seriously injured being the elm, the soft maple, the linden, the birch, and the horse-chestnut. (Fig. 7.) Almost every kind of tree, excepting conifers, is subject to its attack, and it sometimes becomes decidedly injurious in orchards. In Chicago it has been noted as injurious to apple, box-elder, hard maple, Norway maple, poplar, willow, oak, ash, locust, hickory, catalpa, and sycamore, and to several shrubs, including dogwood, button-bush, *Viburnum*, and bladdernut (*Ptelea*). In September and October, 1910, it was found in every one of eighteen towns visited by Mr. John J. Davis, present in small numbers in seven of them, common in nine, and in destructive numbers in two.

This is a well-marked insect, very easily recognized, especially the caterpillar and the egg mass—the two conditions against which measures of destruction must be taken. The hairy caterpillar (Fig. 8), bright yellow in general color and striped with black, and about an inch and a half long when full grown, is a really beautiful object. It may be known by its coral-red head, by two plumelike tufts of long black hairs projecting upward and forward from the back near the head, by a single similar tuft at the hind end of the body, and especially by four thick, short, brushlike clusters of cream-colored hairs arranged, one behind the other, in front of the center of the back. In this condition it may be found upon infested trees in June, July, and August.

There are two generations of the caterpillar in a year in northern Illinois, possibly three farther south. The egg masses (Fig. 9) from which the caterpillars hatch may be found in fall, winter, and early spring. They form, when first deposited, frothy, oval, snowy



Fig. 7. Linden tree in a park in Chicago, defoliated by larvæ of White-marked Tussock-moth (*Hemerocampa leucostigma*). The few leaves on the tree have all appeared since the defoliation.

white patches about an inch in length, on the tree trunks, in the crotches of the larger branches, or in other more or less sheltered places, such as the edges of weather-boards and the under sides of the eaves of porches. Conspicuous objects at first, their color, under exposure to the sooty air of Illinois towns, is soon deadened to a dirty gray. The caterpillar begins to hatch from the over-wintering egg masses about the middle of June in Chicago (June 18 in 1909) and gets its growth in about a month. Feeding at first on the under side of the leaf, which it skeletonizes by eating off the soft tissue, it later eats inward from the edge of the leaf, devouring everything except the principal veins.

The young caterpillars drop down, hanging by silken threads, when the tree is jarred, and sometimes spin down without being disturbed, when they may be blown to a considerable distance by the

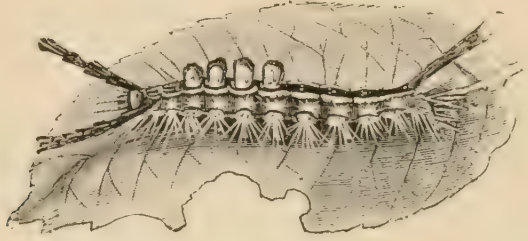


Fig. 8. White-marked Tussock-moth, *Hemerocampa leucostigma*, larva. Natural size.

wind. When nearly full grown, they are great travelers, going from tree to tree and even moving in large numbers from a defoliated tree to others near by. When full grown, the caterpillar



Fig. 9. White-marked Tussock-moth. *Hemerocampa leucostigma*, cocoons and egg masses on tree trunk in a park in Chicago.

spins, on the tree, a delicate grayish cocoon of silken web mixed with its own long hairs. It changes to a pupa within a few hours after the cocoon is finished and continues in this condition from ten days to two weeks.

The adults are moths, the females (Fig. 10) of which differ very widely from the males (Fig. 11) in the fact that they are almost absolutely wingless. The males have good wings and at



Fig. 10. White-marked Tussock-moth, *Hemerocampa leucostigma*, female and egg masses. Natural size. (Connecticut Experiment Station)



Fig. 11. White-marked Tussock-moth, *Hemerocampa leucostigma*, male. Natural size.

least the average power of flight. They are of an ashy gray color, with dark wavy bands across the fore wings, a small black spot on the outer edge near the tip, a blackish stripe beyond this, and a minute white crescent near the hind angle. The wings, when expanded, measure about one and a fourth inches across. The female has little of the appearance of a moth, her wings being reduced to the merest rudiments. Her thick, oblong-oval body is of a light gray color, with rather long legs, and is distended with eggs. When she comes out she lays her egg mass on the cocoon from which she emerged—a fact which makes it plain that the species can spread only by way of the wandering caterpillars, or by the transportation of egg masses on young trees. The eggs of the last generation are ordinarily produced in September and the winter is passed in this condition.

Many insect parasites infest the pupa and do much towards holding the species in check. They are not usually abundant enough, however, to control it completely. In the fall of 1907, for example, one of my assistants reported that 75 percent of the cocoons of the tussock-moth in the Chicago parks were parasitized, but the caterpillars were nevertheless very numerous and destructive the

following year. Birds eat them, but not freely enough in the larger cities to reduce their numbers materially.

Three measures of destruction are applicable to this pest and sufficient for its control. These are the destruction of the egg masses in winter, banding trunks of uninfested trees in spring, and spraying infested trees in summer. The trunks and larger branches of trees, as well as all objects surrounding those infested the season before, should be carefully examined in winter and spring for egg masses, and all these within reach should be scraped or cut away and burned or otherwise destroyed. Those beyond convenient reach may be killed in place by touching each egg mass with a sponge or brush attached to the end of a long pole and dipped in crude creosote.

As the insect spreads from tree to tree only in the caterpillar stage, an uninfested tree may usually be protected completely by banding the trunk in such a way that the caterpillars from adjacent trees can not climb beyond the band. Sometimes, however, the branches of trees intermingle or touch in such a way that the caterpillars may go from one tree to the other without coming down to the ground. These bands should be applied to the tree soon after the caterpillars begin to appear in spring, and they should be renewed from time to time as they are made useless by exposure to the weather.

Either one of two kinds of bands may be used. The trunk may be surrounded, at a convenient height, by a belt nine inches wide of what is known as tree tanglefoot, applied with a brush; or bands of cotton batting about four inches wide may be tied closely about the tree by a string passed around the middle of the band, the upper half of which should then be turned down over it.

Where the preceding measures have been neglected and trees are being defoliated, the injury may be stopped by spraying with Paris green or arsenate of lead. This, however, is a difficult and somewhat expensive operation with large trees, and may be rendered unnecessary by destroying the egg masses and banding the trees as above described.

THE BROWN-TAIL AND GYPSY MOTHS

(*Euproctis chrysorrhæa* Linn. and *Porthetria dispar* Linn.)

These two frightful insect pests, altho present in America, the first for about forty years and the second for nearly half as long, have neither of them become established in Illinois, or indeed made any permanent appearance outside of New England. It will probably be long before the gypsy moth becomes an inhabitant of this state, its powers of migration being limited to the larva. The female, altho well provided with wings, has a very heavy body, and does not fly. The brown-tail moth, on the other hand, is a

strong, swift flier, and is virtually certain to occupy the whole country in due time, and it is further particularly likely to be introduced into the state direct from its European habitat on nursery stock imported from France. It winters in the caterpillar stage partly grown, hundreds of young collecting in single colonies on the trees, where they hibernate in closely webbed nests (Fig. 12). Hundreds of these nests containing living young were sent, in 1909, in-



Fig. 12. Brown-tail Moth, *Euproctis chrysorrhœa*, winter nests. Natural size. (Connecticut Experiment Station.)

to Illinois from France, and only the most active and fortunate inspection work prevented their escape in this state that winter. Worse than this, however, infested cases of nursery stock originating in France were reshipped into Illinois from other states where the force of inspectors was not sufficient to deal with the shipments arriving, and danger from these sources will continue year after year unless other states strengthen their inspection systems. Furthermore, since stock received in Iowa was shipped to this state that winter bearing living brown-tail caterpillars, it is extremely likely that the part retained in Iowa was similarly infested and that the brown-tail has thus obtained a lodgment there and possibly in other states adjacent to Illinois. If this is the case it will presently spread to our state also, especially as the moth flies long distances before the prevailing winds. It is important, for these rea-

sons, that our people should be fully informed and carefully instructed in advance in order that the first of these insects to appear may be detected and destroyed without delay.

The brown-tail moth is a caterpillar (Fig. 13) in the destructive stage, and, of course, goes thru the four stages of egg, larva, pupa, and adult. It is easily distinguished in the last of these stages

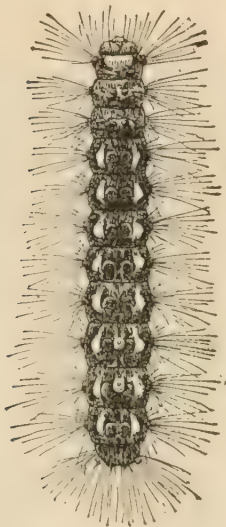


Fig. 13. Brown-tail Moth, *Euproctis chrysorrhæa*, larva. Natural size. (Massachusetts Experiment Station.)



Fig. 14. Brown-tail Moth, *Euproctis chrysorrhæa*. Slightly enlarged. (Massachusetts Experiment Station.)

from any American insect by the character to which it owes its name of "brown-tail," namely, a thick brushlike tuft of orange-brown hairs at the tip of the abdomen, especially in the female (Fig. 14). Otherwise both sexes are pure white thruout, except that occasionally there may be a few black spots on the fore wing of the male. They measure about an inch and a quarter from tip to tip of the expanded wings. Any pure white moth of approximately this size with an orange-brown tuft of hairs at the tip of the abdomen may be at once set down as the brown-tail; and any one seeing it in Illinois will render a notable public service by reporting the fact promptly to the State Entomologist, at Urbana, Ill.

The winter nests of these caterpillars are also easily identified, since no native Illinois species hibernates on either tree or shrub in colonies of living caterpillars inclosed in a web. Any such cluster of young caterpillars so protected by a common web may consequently be set down at once as the brown-tail and should, of course, be promptly destroyed and the facts reported to the Entomologist. Nurserymen importing European seedling stock can

not guard too carefully against the accidental importation of this insect pest, as it is widespread in Europe, breeding abundantly on hedges, trees, and various shrubs, and making its way into the nursery from infested surroundings.

The brown-tail feeds upon practically all deciduous trees and many shrubs and even upon herbs. Thousands of fruit trees in the vicinity of Boston have been killed by it, and damage to maples and elms in wooded regions has caused the forest to appear brown in June, an injury which, if repeated for three or four years, has killed many trees. As the caterpillars pass the winter about a quarter grown, they begin to devour the leaves of trees as soon as these put out in spring, and even eat the buds and blossoms before the leaves have spread. Old trees may thus lose all their buds, or, if not, the foliage itself may be devoured at a later date.

The caterpillar reaches its full size in New England during the last half of June, and the moths emerging, fly about and lay their eggs some twenty days later. The small round eggs are laid in brownish masses (Fig. 15) on the under side of leaves, each mass



FIG. 15. Brown-tail moth, *Euproctis chrysorrhæa*, egg masses on leaves. Natural size. (Connecticut Experiment Station.)

two-thirds of an inch long by a fourth of an inch wide, and containing about three hundred eggs. The full-grown caterpillar is about two inches long, reddish-brown, with an interrupted white stripe on each side and two red dots on the back near the hind end. It is also blotched with orange and is covered with tubercles bearing long barbed hairs, those on the back and sides with short brown hairs additional, which give them, when magnified, a velvetlike look. The young hibernating larvæ are blackish, with reddish-black hairs and black heads. The pupa is formed among the leaves on the infested tree or shrub, most frequently at the tips of the branches, where several caterpillars may spin a loose web together, each forming, how-

ever, its own cocoon within the web. When the insect becomes abundant, cocoons may be found under fences and at the edge of clapboards on houses, and in many similar places.

One of the most disturbing peculiarities of a brown-tail infestation is the fact that the long barbed hairs already mentioned are covered with a poisonous excretion, and that they readily pierce the skin, causing an irritating rash which occasionally results in serious illness. "Indeed," says Dr. Howard, "it is not necessary for the caterpillar itself to come in contact with the skin; at certain times of the year it seems as though the hairs were actually floating about in the air. At the time of the caterpillar's change of skin, and particularly at the time of the spinning of the cocoon and the final change, certain of these hairs appear to become loosened in such a way that they are carried by the wind." Others report that these poisoned hairs may collect on clothing hanging on the line, to the intense annoyance of those who wear it.

The readiest and most obvious means of controlling the brown-tail moth, and certainly the easiest one, is the collection and destruction of the winter nests after the leaves have fallen. After April the only practical remedy is spraying the trees with an arsenical mixture. The young caterpillars are readily enough destroyed with arsenate of lead, but the older ones become resistant to poison sprays, and as much as five pounds of the arsenate to a barrel of water has been found necessary to kill the full-grown caterpillar.

When this insect appears within our borders it will be most destructive in parks and towns and forest plantations, since these are not regularly sprayed and will require a special treatment to protect them. It will also aid the San Jose scale in putting out of business the neglectful or indifferent orchardist, but the business fruit grower, who values his property and takes care of it as well as he can, will have much less to fear from this insect, since his ordinary spraying operations will be practically certain to destroy it as it enters his orchard. The fact, however, that the full-grown caterpillar requires a heavier insecticide treatment than does the codling-moth and the canker-worm, for which most of our spraying is done, may make it necessary to go over the orchard in winter to remove and destroy the hibernating colonies.

The gypsy moth may be more briefly considered, altho it is even a more destructive pest than the brown-tail, especially for the reason that it eats the leaves of evergreens—trees which are often killed by a single defoliation. It is conveyed to distances in the caterpillar stage only by accident. Passing wagons, automobiles, trolley cars, or even railroad trains, may carry the caterpillars to uninfested districts, but in this way its spread is slow, especially as all possible measures are being taken in infested districts of New England to keep the roadsides free from the pest.

and thus to reduce to a minimum the possibility of an extensive spread.

The caterpillar of the gypsy moth (Fig. 16) is a voracious feeder, eating the leaves of nearly every kind of tree or shrub, and devouring sometimes also grasses and field and garden crops. The very fact that it spreads but slowly makes it locally all the more



Fig. 16. Gypsy Moth, *Porthetria dispar*, larvæ. Natural size.
(Connecticut Experiment Station.)

injurious, since it accumulates in enormous numbers upon infested localities. Forests, orchards, gardens, parks, and street shrubs and trees may be stripped of every leaf between the first of May and the middle of July.

The insect winters in the egg stage, the eggs being plastered in conspicuous masses (Fig. 17) on the trunks of trees and on various other objects. They may readily be destroyed by touching them with a mixture of creosote oil, 50 percent, carbolic acid, 20 percent, turpentine, 20 percent, and coal-tar, 10 percent, in sufficient quantity to soak the mass. The caterpillar may also be killed on the trees with arsenical poisons, but these must be applied in unusual quantities, since the gypsy moth is not readily poisoned in the caterpillar stage. Five pounds of arsenate of lead to fifty gallons of water will kill the young, but even this can not be depended upon for the full-grown caterpillars. These are about three inches long, of a sooty or dark gray color. Along the back is a double row

of blue spots, followed by a double row of red spots, and the back is marked with yellow. The cocoon is formed among the leaves like that of the brown-tail and the moths appear from the middle of July to the middle of August. The male is bluish-yellow, expanding about an inch and a half, and the female (Fig. 17) is



Fig. 17. Gypsy Moth, *Porthetria dispar*; female moths, laying eggs on bark. Natural size. (Connecticut Experiment Station.)

nearly white, somewhat spotted and barred with black. Its wing expanse is about two and a fourth inches. The female is very sluggish and so heavy that she can not fly; but the male is an active flier.

The oval egg masses, about one and a half inches long by three-fourths that in width, are laid in summer on the trunks of trees, on fences, on the sides of houses, and in various other places. Large holes in old trees are often found filled with them. The caterpillars feed principally at night, especially after they reach some size, and they seek to hide during the day, often coming down upon the larger limbs and trunk of the infested tree in search of hiding places. This habit has led to the use of bands of burlap tied around the trunks of trees, under which the caterpillars may rest during the day and where they can be easily destroyed by hand.

The probabilities of widespread destruction to forest, park, and orchard properties by these insects are greatly reduced by the truly

tremendous and unexampled work being done by the United States Department of Agriculture and the state of Massachusetts in bringing from Europe the native parasites of these insects. This work is making successful progress, and it is all the more hopeful because the parasites of both these species seem to keep them substantially in check in the Old World, where they rarely become seriously destructive.

THE FOREST TENT CATERPILLAR

(*Malacosoma disstria* Hbn.)

There occasionally appears in the forest region of southern Illinois an overwhelming eruption of caterpillars which denude large areas of woodlands, especially the oaks and the maples, and the black and sweet gum trees, and thence invade orchards, parks, and town premises, carrying the same destruction to fruit and shade trees generally. This is one of the species which moves in masses such as actually to delay the passage of railroad trains, piling up



Fig. 18. Baltimore Oriole attacking nest of Forest Tent Caterpillar, *Malacosoma disstria*. (New Hampshire Experiment Station.)

on the rails several inches deep. It is known to entomologists as the forest tent caterpillar, but in the South it is commonly called "the caterpillar" simply. The name of "tent caterpillar" is, in fact, inappropriate for it, since it spins but little and never makes a tent. It is closely allied, however, to the common tent-caterpillar of eastern orchards and has received its common name because of this resemblance.

When full grown (Fig. 19) it is about two inches long and a quarter of an inch thick. It is of a brownish general color, and is conspicuously marked with a series of whitish or cream-colored spots down the middle of the back. On the upper part of each side

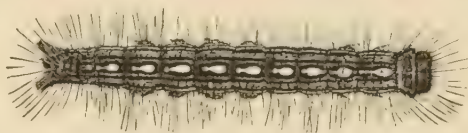


Fig. 19. Forest Tent Caterpillar, *Malacosoma disstria*, larva. Natural size.

is a rather broad blue line edged above and below with a yellowish-brown line. When disturbed it drops from the branch and hangs suspended in mid-air by means of a fine thread spun from the mouth. In moving about on the tree these caterpillars follow each other in single file. They feed mostly in the tops of the trees, often eating out the central part of the base of a leaf, allowing the remainder to fall to the ground. When preparing to molt, they mass together on the limbs and may continue thus for a day or two. They often form similar masses in stormy weather and in general when at rest. The eggs (Fig. 20) are laid in a thick hard band around a twig and covered with an impervious varnish. From these the young hatch in early spring, sometimes before the appearance of the leaves on which they depend for food.

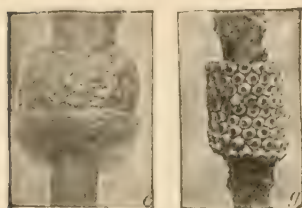


Fig. 20. Forest Tent Caterpillar, *Malacosoma disstria*: e, egg ring recently laid; g, hatched egg ring. Slightly enlarged. (Cornell Experiment Station.)

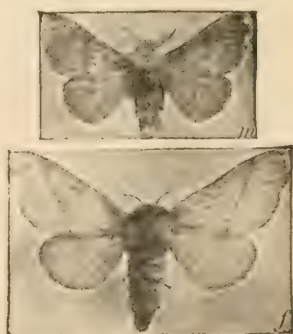


Fig. 21. Forest Tent Caterpillar, *Malacosoma disstria*: m, male; f, female. Natural size. (Cornell Experiment Station.)

They are capable, however, of fasting for a considerable time without injury, and they may even survive the destruction of the leaves by late frosts. They scatter for pupation late in May or early in June, spinning cocoons which they fasten among clusters of leaves or exposed on fences and in other similar situations. There is but a single generation in a year. The parent moths (Fig. 21) measure about an inch and a quarter across the expanded wings. The general color is brownish-yellow and the fore wings are marked by two straight dark brown lines which cross them obliquely, parallel with each other and the hinder edge.

Trees may be protected by spraying with arsenical poisons shortly after the young caterpillars begin to appear, or by clipping off in winter the twigs bearing the conspicuous belts of eggs and destroying these by burning. Even overwhelming hordes may be arrested by surrounding the tree trunk with a band of cotton batting about four inches wide, tied around the middle with a string, the upper part being then turned downward over the string. Or, the trunk may be surrounded with a band of printers' ink applied as described in the article concerning the common canker-worm (p. 488).

THE COMMON CANKER-WORM, OR SPRING CANKER-WORM

(*Paleacrita vernata* Peck)

The common canker-worm is best known as a pest of the apple orchard, but it is sometimes even more destructive to elms (Fig. 22) than to apple-trees. It feeds also on cherry, at first eating small holes thru the leaves, but when larger devouring the whole leaf except the midrib and some of the coarser veins. Modern methods of orchard management require a regular and frequent spraying with arsenical poisons as a protection of fruit against the codling-moth, and this has the incidental effect—often unnoticed by the orchardist—of speedily killing off any colony of canker-worms which may have chanced to make a start in the orchard. Hence it is only neglected orchards, or those not in bearing either because too young or by reason of a crop failure for the year, which are liable to serious canker-worm injury.

With the elm, however, the case is different. The canker-worm lives on this tree as willingly and successfully as on the apple. Elms are rarely sprayed in Illinois, and if the canker-worm once comes to infest them there is no natural end to the injury except the death of the tree, unless, indeed, the parasites of the insect and other natural checks on its increase may happily suppress it before that event.

The spraying of large elms is, of course, a difficult and expensive operation, and canker-worms are less susceptible to arsenical poisons than many other insects. There is, however, a much cheaper and more convenient method of protecting the elm, by which advantage is taken of two features in the economy of the insect. When the caterpillars are full grown they leave the tree to pupate in the earth, and the female moth emerging, being wholly without wings, can only reach the tree to lay her eggs by climbing up the



Fig. 22. Injury to elms at Calamus Lake, Niantic, Illinois, by common Canker-worm (*Paleacrita vernata*).

trunk. If this is encircled at the proper time by a sticky band impassable by her or by young canker-worms just hatched from the egg, the tree is virtually secure against canker-worm injury except as worms may reach it from neglected trees with which its own branches interlace.

Altho the female canker-worm (Fig. 23, *b*) is wingless, the male (Fig. 23, *a*) has two pairs of rather large, thin, ashy or brownish-gray wings, the first pair with a broken whitish band near the outer edge and three interrupted brownish lines between that and the body. There is also a short oblique black mark near the tip of the wing, and a black line at its edge at the base of a fringe of hairs. The eggs (Fig. 24, *b*) are about .03 of an inch long, oval in outline, and of a pearly luster at first, changing to yellowish-green with a golden, greenish, or purplish iridescence. They are

laid in irregular masses, often as many as a hundred together, and usually hidden in crevices of the bark of trees.

The female comes out of the ground to lay her eggs from February to April, the date varying with the latitude and the season. The young caterpillars appear about the time that the apple-tree unfolds its leaves, commonly, in this state, in April or early May, and they usually get their growth in about a month from the time when they issue from the eggs. They then go into the ground to a depth of two to five inches, each one in a small cell, where they change to the chrysalis, remaining there until the following



Fig. 23. Common Canker-worm, *Paleacrita vernata*: a, adult male; b, female; c, portion of female antenna; d, joint of abdomen, enlarged; e, ovipositor.

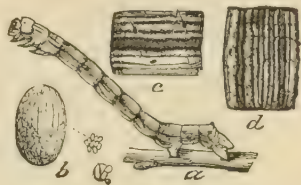


Fig. 24. Common Canker-worm, *Paleacrita vernata*: a, larva; b, cluster of eggs, natural size, with one enlarged; c, side view of one of the segments, d, back view of same, both enlarged.

winter or early spring, when the change to the adult insect takes place. There is thus but a single generation produced each year. The canker-worm is widely distributed thruout the country and may occur in destructive numbers in any part of Illinois. Its feeble power of locomotion prevents its rapid spread in any locality, but by concentration of its injuries it is the more destructive where it does occur.

In its injurious or caterpillar stage (Fig. 24, a) it is readily recognized. It has a long and slender form and the habit of a "looper" or measuring worm. When not eating it usually adheres only by its hinder prolegs, extending the body from this point of support at an angle of about 45 degrees. As it is colored much like the bark of a tree, it then has the appearance of a stubbed twig. It also has the habit of spinning down from the tree at the end of a thread, particularly if the branch is jarred or shaken. Both the just-mentioned habits are doubtless advantageous to it; the first by concealing it to some degree from the observation of birds and the second by putting it beyond their reach. The full-grown canker-worm is about nine-tenths of an inch in length and may vary from greenish-yellow or gray to dusky or even dark brown, with paler stripes along the sides. A close examination will show also two light lines running close together along the middle of the back.

The young are usually olive-green. The wingless female, with its small gray body from a quarter to two-fifths of an inch in length and its rather long legs, gives more the impression of a spider than that of a moth. The chrysalis is pale grayish-brown, with a dark green tinge on the wing sheaths, and measures about a third of an inch in length.

This insect has not recently been abundant in Chicago, but its capacities for injury are well illustrated in a recent attack on elms at Big Rock, Kane county. Some ten years ago it was generally prevalent thruout the south-central part of the state, both in towns and in forests, to which it had apparently escaped from neglected orchards, although in some cases orchards were invaded in turn from adjacent forests. A most threatening attack was made on the magnificent old elms of Jacksonville, but a vigorous campaign, first of spraying and later of the application of adhesive bands, presently brought the outbreak under control.*

A cheap and available band for the trunk of a tree is made by laying around the trunk first a strip of unglazed cotton batting two or three inches wide and over this a four- to six-inch strip of tarred paper tied around the middle with ordinary wrapping twine. Upon this paper belt should be spread a layer a quarter of an inch thick of cheap printers' ink with which a small amount of car wheel oil has been mixed, just enough to make it easy to spread. If the tarred belt becomes slightly hardened by exposure so as to permit an insect to cross, it may be made sticky again by brushing it with a little of the same kind of oil. The cotton batting beneath the paper is necessary to keep the young canker-worms or the female moths from crawling up behind the paper where the roughness of the bark would give them passageway. These bands should be placed on the tree as early as the middle of February or the first of March, the time varying according to the latitude, and they may be safely removed by the middle of June. The cost of the bands will approximate ten cents a tree.

If the canker-worms have already ascended the tree, it is sometimes necessary to spray the leaves with an arsenical poison, which may be either arsenate of lead or Paris green, the latter at the rate of one pound of the poison and one pound of lime to seventy-five gallons of water. If the arsenate of lead is used, three pounds of it dissolved in fifty gallons of water will kill even the full-grown caterpillars.

*The Canker-worm on Shade and Forest Trees. By S. A. Forbes. Twenty-second Report State Ent. Ill., page 139.

THE LILAC BORER

(Podosesia syringæ Harris)

Among the borers whose instincts lead the female to choose, for the deposit of her eggs, scars or injured places on the bark of trees and shrubs, with the effect greatly to increase the injury and



Fig. 25. Trunk of ash in one of the parks in Chicago, showing injury by the Lilac Borer, *Podosesia syringæ*.

to prevent its healing, is a species commonly known as the lilac borer (*Podosesia syringæ*), because it was first noticed to infest lilacs. It is much more important, however, by reason of its injuries to various species of true ashes,* and to the mountain ash,

*It has been found injurious to the lilac (*Syringa* sp.), to the mountain ash (*Sorbus americana*), and to the white, green, and English ashes (*Fraxinus americana*, *lanceolata*, and *excelsior*).



Fig. 26. Trunk of ash, in one of the parks in Chicago, showing injury by the Lilac Borer, *Podosesia syringæ*.

on the trunks and branches of which it produces large, rough, scar-like outgrowths from knots, roughened places, or wounds, by undermining the bark and boring into the wood. (See figures 25 and 26.)

The eggs are laid in summer in masses on rough, scarred, or knotty places. They hatch in about six days and the young borers eat thru the bark into the outer layers of the sapwood, where they mine irregularly about, penetrating the harder wood and going to the center of small branches. (Fig. 27.) In fall, when they are nearly or quite full grown, they make a hibernating cell by plugging up the burrow both before and behind with frass, and there they pass the winter as larvæ. They do practically no bur-

rowing in spring, but pupate in April or the first part of May. As a preparation for pupation, they burrow outward and cut their way thru the bark, leaving only a thin outer film to close the pupal cavity. By means of short teeth with which each segment of the abdomen is armed, the pupa, when mature, works its way out of



Fig. 27. Lilac Borer, *Pod-
osia syringæ*. Burrows
in ash made by larvæ.
Slightly reduced.

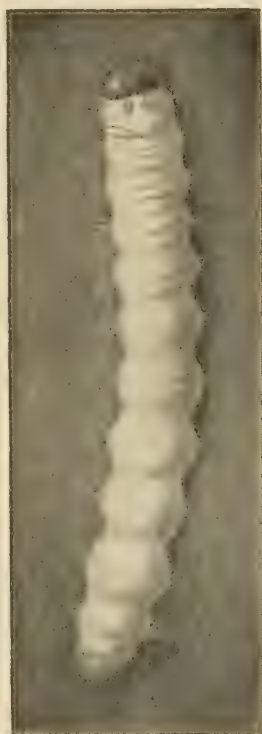


Fig. 28. Lilac Borer, *Pod-
osia syringæ*, larva. About
5 times natural size.

its gallery until it projects some three-quarters of an inch. The winged insects, altho moths, closely resemble wasps in movement, color, and form. They make their appearance from the latter part of April to the middle of June in central and northern Illinois.

The borer or larva (Fig. 28) is very variable in length. It is white, yellowish anteriorly, the head of a bright mahogany color, becoming very dark at the mandibles, which are stout, broad, and provided with five teeth. The segments of the body are distinctly

marked, somewhat flattened, the first segment reddish and leathery above, the last with a broad yellowish patch.

The moth (Fig. 29) has a black head, a deep brown thorax more or less marked with bright chestnut-red, and a black abdomen sometimes marked with chestnut, but sometimes with a small yellow spot on each side of the fourth segment, or with the segments banded with yellow. The femora are black, the anterior pair of the tibiae orange, the middle and hind tibiae black with orange bands.



Fig. 29. Lilac Borer, *Podosesia syringæ*, adult. Slightly enlarged.

The tarsi are yellow, the hind pair with a black band above. The fore wings are deep brown, with a violaceous luster and usually with a rusty red dash on the outer part. At the base is a transparent streak. The hind wings are transparent and yellowish, the veins, discal marks, and margins deep brown, sometimes tinged with red.

The spread of the wings is from an inch to nearly an inch and a half, the females being considerably larger than the males.

This insect is very abundant and destructive, especially to the green ash in Chicago parks, and has been bred by us also from the white ash at Kankakee. Its injury is very noticeable and characteristic, especially on the trunks of small trees. Sometimes the smaller branches break off at the point of injury, but this does not usually happen until after the moth has escaped. George D. Hulst says, writing of these insects in New York: "In this section they are very destructive to both lilac and English ash. Large shrubs of lilac are now very rarely seen, and the English ash is being rapidly exterminated. In the latter I have seen the wood completely riddled with the holes made by the larvæ and the entire tree dead."

To check the multiplication of the species and the spread of the injury it will be sufficient to cut away and burn infested branches

and trees in winter. It may also be practicable to protect trees especially exposed by painting rough, knotty, and injured places on the bark with a poison mixture commonly used by orchardists to prevent infestation by ordinary borers. A number of substances are available for this purpose, the simplest of which, perhaps, is a mixture of soft soap and soda, with the addition of Paris green. The following is a convenient formula: To a saturated solution of washing soda add soft soap sufficient to make a thick paint, and to each ten gallons of this wash add a pint of crude carbolic acid and half a pound of Paris green. This may be painted thickly upon scarred, roughened, or knotty surfaces in April and early May and renewed as necessary until August.

TWO POPLAR BORERS

(*Memythrus tricinctus* Harris)

(*M. dollii* Neum.)

Two boring caterpillars, similar in appearance, but differing in the larval or boring stage mainly in size, infest poplars in this state to an injurious degree. They are most destructive to young nursery trees, particularly to the balm of Gilead (*Populus candicans*), but the Carolina poplar (*P. deltoides*), Figure 30, is also sometimes badly infested. They are generally present thruout Chicago, often infesting trees which are likewise injured by a boring larva, *Cryptorhynchus lapathi*, discussed on p. 40. They have also been found by us in park and street trees in several Illinois cities and towns from Centralia northward. In the case observed by us in Chicago, the eggs of one of these species, which one we do not know, were deposited July 22, mostly in a crevice of the bark or in the neighborhood of a bud, and young larvæ were first seen July 26, altho some of these had apparently hatched at least a week before. The borers winter in the larval stage in the wood, pupate in spring, and come out as winged moths in June and July—at various dates from June 18 to July 26, if we may judge by results obtained in our insectary. From a willow in Cook county a specimen of *M. tricinctus* was bred which emerged July 2.

The boring larvæ are whitish caterpillars, with brown or yellowish heads and a smooth neck shield. The two species are most easily distinguished by the markings of the head and by the number of hooks on the abdominal legs. In *M. tricinctus* the head is yellowish and mottled with large patches of brown, while the abdominal feet have from eighteen to twenty-two hooks in a row. In *M. dollii*

(Fig. 32) the head is brown with large darker patches on the sides, and a black band or blotch between the antennæ. The abdominal feet have ten to fifteen hooks in each row. Both these species are



Fig. 30. Small poplar infested with sesiid borers (*Memythrus*).

distinguished from some other borers of their family by the fact that the first segment of the thorax bears two oblique dark marks, approaching each other behind.

The winged insects are readily distinguished by a comparison of the wings and abdomens. In *tricinctus* (Fig. 35) the fore wings are violaceous-black, the hind wings are transparent, and the abdomen is black with three or four yellow bands. In *dollii* (Fig. 36) the fore wings are brown, the hind wings are brown and



Fig. 31. Poplar Borer *Memythrus tricinctus* or *dollii*, egg. Greatly enlarged.



Fig. 32. Poplar Borer, *Memythrus dollii*, larva. About 3 times natural size.

opaque, except at the base, and the abdomen is brown, sometimes with one or more yellow bands.

In our work with these borers it was not at first known that two species were concerned, and the larvæ were not distinguished in our notes. It was only when the adults appeared that the specific distinctions were established.



Fig. 33. Poplar Borer, *Memythrus tricinctus* or *M. dollii*, pupa. About 3 times natural size.



Fig. 34. Poplar Borer, *Memythrus tricinctus* or *M. dollii*, anal end of pupa. Greatly enlarged.



Fig. 35. Poplar Borer, *Memythrus tricinctus*, adult female. About twice natural size.

A third species, allied to the two above mentioned, but more commonly found infesting ninebark (*Opulaster opulifolius*), has been once bred by us from poplar at Chicago.



Fig. 36 Poplar Borer, *Memythrus dollii*, adult. About twice natural size.

A VIBURNUM BORER (*Sesia pictipes* G. & R.)

A boring caterpillar, somewhat larger than that described from ninebark and dogwood, but otherwise extremely similar, has been found doing considerable damage to viburnum shrubs in all the parks of Chicago, and, in one case, to wild black cherry at Riverside. It burrows beneath the bark, frequently killing the branches. It spends the winter in the larval stage, and has emerged in our breeding cages during the latter part of June, from the twentieth to the twenty-fourth. Elsewhere it is reported to emerge during June and July. The species is known also from plum, cherry, beach-plum, peach, Juneberry, and chestnut, and has been bred from the black-knot of the plum.

The placing of the eggs has not been noticed by us, but another observer, Dr. Bailey, found a cluster of them, ninety-two in number,

on the under surface of loosened bark a few inches from the root of a badly infested plum-tree.

The removal and destruction of infested branches at the proper time of the year, that is, during the winter and spring, is the only measure practicable for the control of this pest.

The winged insect has a blue-black head, thorax, and abdomen, the thorax with a narrow pale line each side, and the abdomen with a narrow pale yellow ring on the second and fourth segments, encircling the body completely on the latter. The fore wings are transparent, with very narrow blue-black margins, and a narrow, straight, discal mark. The inner margin is sometimes scaled with pale yellow. The hind wings are transparent, with a very narrow outer margin and no discal mark. The spread of the wings is from 15—26 mm., the smaller specimens being males.

THE MAPLE BORER

(*Sesia acerni* Clem.)

The worst of the borers of the maples, both hard and soft, very common and destructive to soft maples in Chicago, and common also in towns thruout the state, is a white or nearly white caterpillar (Fig. 37, *a*) about half an inch long when full grown, with a yellow head and a neck shield of a paler tint. It is especially injurious to young trees, but usually originates in some surface injury which attracts the parent moth in search of a place of deposit for her eggs.

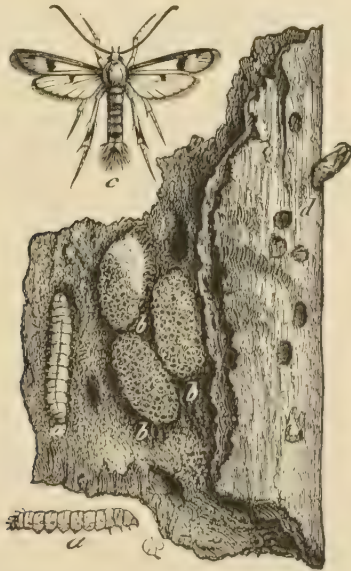


Fig. 37. Maple Borer, *Sesia acerni*: *a*, *a*, larvæ; *b*, *b*, *b*, cocoons; *c*, adult; *d*, pupal skin left in mouth of burrow.

It burrows mainly just beneath the bark, where it can be found and destroyed in fall or early spring. It comes to maturity in May or June, eats its way nearly thru the bark, and pupates there. We collected the adult in considerable numbers, at electric lights, in Urbana, from May 18 to June 3, 1887. When ready for its transformation the pupa wriggles partly out of its burrow, and the adult insect escaping leaves the empty pupa-case still sticking in the opening, which is about an eighth of an inch across. (Fig. 37, d.)

The adult is a handsome wasplike moth (Fig. 37, c; Fig. 38) with thin transparent wings, a slender yellow body banded and trimmed with red, and a brushlike tuft of hairs at the tip of the



Fig. 38. Maple Borer, *Sesia acerni*, adult. About 3 times natural size.

abdomen. The eggs are laid chiefly in rough or injured places, almost wholly in the trunk of the tree, and not in its branches. The effect of the injury is to kill the bark undermined, and to enlarge surface wounds and prevent their healing, converting them into permanent, rough, and very unsightly scars. Sometimes the tree is killed by a girdling of the trunk.

To prevent attack by these borers the tree should be protected from injury, and such wounds as it receives should be painted over or covered with grafting wax. Dr. Felt, State Entomologist of New York, says that "the deposition of eggs could probably be prevented to considerable extent by treating the trunks of trees about the middle of May with a wash prepared as follows: Thin one gallon of soft soap with an equal amount of hot water and stir in one pint of crude carbolic acid (one-half pint, refined), let it set over night and then add eight gallons of soft water. Apply thoroughly to the trunk, especially about all crevices and wounds, from the ground to about six or eight feet high, and renew if necessary before the middle of June." As the borers work near the surface, they can be easily dug out and destroyed in fall.

THE NINEBARK BORER

(Sesia scitula Harris)

Dogwood and ninebark shrubs (*Cornus* sp. and *Opulaster opulifolius*) in the Chicago parks are generally infested, and often seriously injured, by a boring or girdling caterpillar (Fig. 39) which works just beneath the bark, mainly at the junction of the branches



Fig. 39. Ninebark Borer, *Sesia scitula* larva.
About 3 times natural size.

or in the neighborhood of an old dormant bud. The burrows of the borer sometimes extend lengthwise of the branch, and sometimes girdle it near its origin. In 1908 nearly every shrub of the ninebark in Washington Park was infested, and many of the branches were killed by this larva. The species also infests the chestnut, and has been bred from galls on twigs of the oak.

The creamy white larva, half an inch long in September, passes the winter in its burrows, and emerges, according to our observations, in late June or in July. The head is brown, darkening almost to black towards the mandibles. The prothorax is slightly brownish, with two oblique brown markings on its posterior half. The re-



Fig. 40. Ninebark Borer, *Sesia scitula*, adult female.
About 3 times natural size.

maining segments are creamy white, except the last, which is pale reddish-brown.

The winged insect (Fig. 40) is deep blue-black on the thorax and abdomen, the former with a yellow line and a yellow patch on each side, and the latter with a yellow line at its base and, in the

male, a narrow yellow ring on the second and fourth segments, broadening below on the fourth to cover the whole surface. In the female the fourth segment is yellow both above and below. The head and antennæ are black, the femora blue-black, and the tibiae yellow. The fore wings are transparent, except the borders and the discal mark, which are blue-black. The outer margin is marked with yellow rays. The hind wings are transparent, with very narrow blue-black margins. The spread of the wings is from 18—22 mm.

This insect can evidently best be destroyed by cutting out and burning infested branches in winter or early spring.

THE BAG-WORM

(*Thyridopteryx ephemeraformis* Harris)

One sometimes sees hanging from the branches of trees, in late summer or in fall or winter, especially in the southern part of the state, rough excrescences, about two inches long, shaped somewhat like a spindle full of yarn, soft to the touch, and more or less covered with pieces of dead leaves which seem to be woven into their web-like substance (Fig. 41, *f*). In summer it may be further noticed

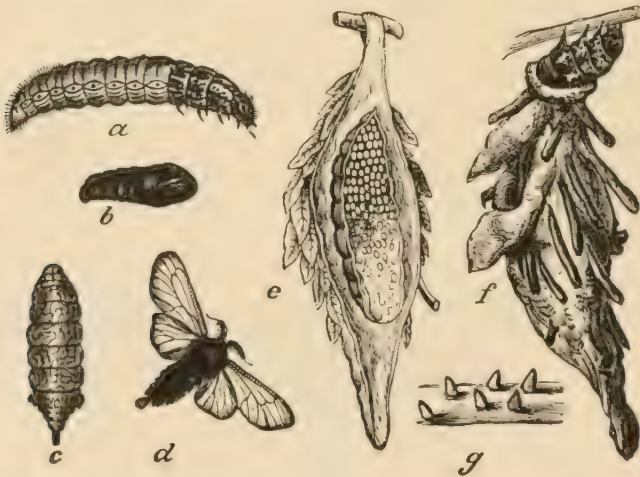


Fig. 41. Bagworm, *Thyridopteryx ephemeraformis*: *a*, larva; *b* and *c*, pupa, side and back views; *d*, adult; *e*, case containing the eggs; *f*, larva in case; *g*, eggs. Natural size.

that these spindle-shaped sacks can creep along the twig, and that there projects from the end nearest the twig the head and front part of a caterpillar, the remainder of which is enclosed in the protecting bag. In winter this is hung to the tree by a rather tough ligament composed of material like spider-web. An examination of these peculiar bodies at that season will show either that they are

virtually empty, or that they contain a mass of soft yellow eggs. (Fig. 41, *e*.)

The insect known as the bag-worm, to which these constructions are due, is in several respects one of the most curious in Illinois. Altho the parent form is a moth, the female is wingless and naked (Fig. 41, *c*), looking more like a grub than a moth, and the wings of the male, instead of being covered with scales, are smooth and transparent, somewhat like those of a wasp. (Fig. 41, *d*.) The caterpillar infests a considerable variety of both fruit and shade trees, including among the latter evergreens (especially red cedar and arbor-vitæ, Fig. 42) and several kinds of deciduous trees.



Fig. 42. Bag-worm, *Thyridopteryx ephemeraformis*, cases hanging on arbor-vitæ twig. (Ohio Experiment Station.)

It does its injury by eating the leaves of trees, and its numbers are often such that they may take virtually every leaf off a tree of considerable size.

The eggs, contained during the winter in the bag-like cases on the trees, hatch the following May or June, and the young caterpillars begin at once to spin for themselves small conical cases (Fig. 41, *g*) to which they fasten pieces of leaves from the tree upon which they are feeding. As they grow these cases are enlarged until they take the form and dimensions already described. The caterpillars (Fig. 41, *a*) travel but slowly, and seldom leave the tree upon which they were hatched until they are about full grown,

when they are likely to spin down and wander about. They change to the chrysalis (Fig. 41, *b*) within the bags, which they fasten to the twigs of the trees as a preliminary, but the grublike female moth, destitute of wings and with only minute and useless legs, deposits her eggs within her native sack, works her way out of it, drops to the ground exhausted, and dies. The winged males (Fig. 41, *d*) appear in September and October, and soon thereafter the eggs are laid.

The bag-worm is a southern insect in its general range, and is rarely seen in northern Illinois. It increases in importance southward, and in southern Illinois is often a troublesome pest. In a general trip to eighteen towns, well distributed thruout the state, Mr. J. J. Davis, in 1910, found the bag-worm in four out of six southern Illinois towns visited, but in no others.

The simplest method of destroying these insects is to collect the bags during the winter and burn them—a thing easily done with the aid of pruning shears if they can not be reached by hand. If this measure is neglected, infested trees may be cleared by spraying them with arsenical poisons soon after the hatching of the eggs—the latter part of June or early July. A pound of arsenate of lead to forty gallons of water is a safe and effective poison.

THE POPLAR AND WILLOW BORER

(*Cryptorhynchus lapathi* Linn.)

The weeping willow, the Carolina poplar, the balm of Gilead, and the red birch are ornamental trees of sufficient popularity to make the existence of any insect pest destructive to them a matter of general interest. The Carolina poplar especially has had an enormous distribution of late years in Illinois towns, largely because of the ease and certainty with which it may be raised, and the rapidity with which it grows in our soils.

The advent into this country nearly thirty years ago of a European snout-beetle well known in the Old World as a destroyer of alders, poplars, and willows, and occasionally injurious to birches also, has seriously endangered our American plantations of these trees. Detected first in New York in 1882, and found on Staten Island in 1886, it appeared in considerable numbers near Buffalo by 1896, and the following year was reported as abundant in Boston, Mass., and very destructive there to willows and poplars of all kinds, and to the red birch. By 1901 it had reached northeastern Ohio; in 1903 it was found in two Wisconsin nurseries; and in 1904 it was reported from North Dakota in poplars lately brought into that state from New York. In Illinois it was first seen by us in 1908 in Carolina poplars at Chicago; but once detected there it was soon found to be generally distributed and very destructive to both poplars and willows in all parts of the city. (Fig. 43.) It has not yet occurred,

to our observation, elsewhere in Illinois. Wherever it appears it multiplies locally, but makes a slow spread, a fact apparently due to the sluggishness of the parent beetle, which, although provided with wings, makes extremely little, if any, use of them. In consequence



Fig. 43. Small poplar tree in Chicago showing dying of upper branches resulting from attacks of the Poplar and Willow Borer, *Cryptorhynchus lapathi*.

of this fact, an infested grove may be nearly destroyed before another, near at hand, becomes even infested. It extends its range most readily along watercourses by means of the willows and cottonwoods with which our streams are likely to be fringed. Its spread to distant points seem to have been mainly, if not altogether, by way of the nursery trade, especially that in poplars and willows of various kinds. These facts make it particularly important that

the signs of its presence should be generally known, in order that it may be promptly recognized and suppressed upon its appearance in any new locality.

Injury by this borer may be suspected when the general health of a tree is evidently affected, where there are dead patches of the bark, irregularly cracked open (Fig. 44, 45), or where openings in



Fig. 44. Injury by Poplar and Willow Borer,
Cryptorhynchus lapathi.

the bark give exit to a soft excrement like moist sawdust mixed with fine splinters. The burrows beneath the bark, made chiefly in the cambium layer, are irregular in direction, sometimes girdling a small tree, and show nothing of the symmetrical pattern made by many borers which undermine the bark. Those of the older larvæ dip into the wood, usually reaching the center of the branch unless this is large. These deeper burrows finally become filled with powdered wood and splinters, except a chamber at the farther end in which the larva pupates. In the active boring stage these insects are soft, yellowish, fleshy, cylindrical, footless grubs (Fig. 46) with a pale-brown head and darker mouth-parts. They are half an inch long when they reach full size, which is about the last of June for those most advanced. At this time, however, young larvæ may be found under the bark down to a fifth of an inch in length.

The adult beetles (Fig. 47) begin to appear in July, and continue abroad at least until October. They are well marked and easily distinguished insects, a little more than a quarter of an inch

long, thick-bodied, with a roughened and punctured surface, and a stout curved beak projecting downward from the head. The general color is dark sooty brown, more or less specked and spotted

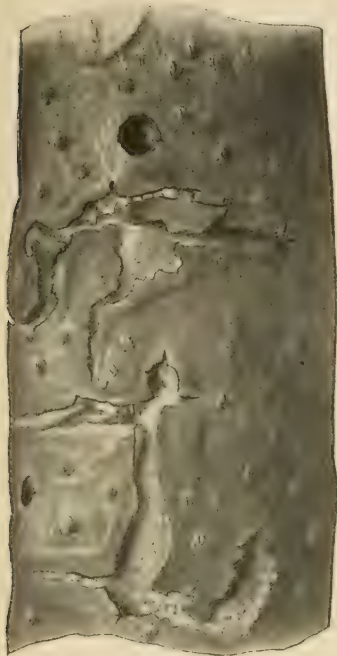


Fig. 45. Injury by Poplar and Willow Borer, *Cryptorhynchus lapathi*.

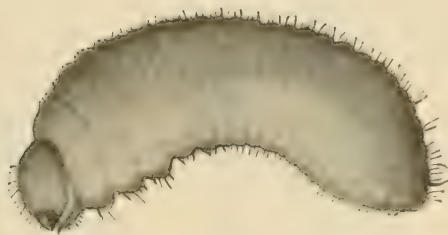


Fig. 46. Poplar and Willow Borer, *Cryptorhynchus lapathi*, larva. About 4 times natural size.

with gray, and there is a very conspicuous large patch of light gray on the hinder end of the wing-covers, contrasting strongly with the adjacent colors. The sides of the prothorax are gray, and there is a pair of rather definite oblique gray marks just behind the front outer angle of each wing-cover. The beetle is slow and lumbering in its movements, and when disturbed drops to the ground like a curculio, without attempting to fly. It feeds upon the cambium layer of the younger branches, which it reaches by puncturing the bark with its snout. It lays its eggs in the older bark, mainly of branches from two to four years old. This the female does by first eating downward into the bark by means of the jaws at the tip of her snout, taking half an hour or more to hollow out a cavity in which the egg is concealed. She then turns end for end, and leaves an egg in the chamber thus made, and presently moves away to repeat the process at another point.

The young hatch mainly in August and September, penetrate at once to the cambium layer, and hibernate there while most of them are still very small. The following spring they continue to work in the cambium until nearly ready for pupation, when they enter older wood.

The dependence of the beetle for food upon the bark of the tree which it infests has suggested the use of poisons for its destruction, and some tests made at the New York Agricultural Experiment Station show that the ordinary arsenical poisons applied as a spray will destroy it. Arsenate of lead is the best of these for the purpose, because of its adhesive quality. Trees to be protected should be thoroly sprayed at intervals of about a fortnight, beginning



Fig. 47. Poplar and Willow Borer,
Cryptorhynchus lapathi, adult. Length,
about one-fourth inch.

with the middle of July and continuing thru August. Moderately infested trees may be saved by cutting out the grubs and covering the wound with tar. Badly infested trees should be taken out and burned, either during the winter or before July 1 of the following season. Nursery trees infested by this insect should be unhesitatingly destroyed, since they are far worse than worthless, and are the principal means of conveying the species to places not previously infested by it.

THE DOGWOOD TWIG-GIRDLER (*Oberea tripunctata* Swederus)

Among the insects whose nice and elaborate instincts connected with the placing of their eggs are the wonder of entomologists, we must class the twig-girdlers, for their careful preliminary operations are such as to suggest a knowledge of vegetable physiology and a prevision of the possible difficulties in the way of the development of their young certainly quite beyond the powers of insect intelligence, and an unsolved puzzle if regarded as a product

of natural selection. The twig-girdler of the dogwood is an example.

This is a small, cylindrical beetle (Fig. 48), about half an inch long and less than an eighth of an inch in diameter, which prepares a chosen twig for the reception of the egg by first cutting a groove around it a few inches from its tip in such a way that the twig



Fig 48. Dogwood Twig-girdler, *Oberea tripunctata*, adult. About 5 times natural size.

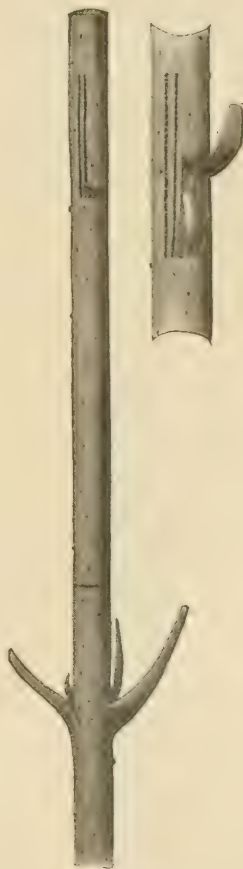


Fig. 49. Cornus twig girdled by Dogwood Twig-girdler, *Oberea tripunctata*, and part enlarged, showing egg in position.

presently breaks off at this point, and afterwards making a second girdle, not so deep as the first, and from two to four inches farther back. (Fig. 49.) It then makes two parallel cuts, about half an inch long, lengthwise thru the bark between the two girdling incisions, and at the proximal end of these makes a short transverse slit in a way to form an angular flap, beneath which it pushes its egg. The effect of all this surgery must be to stop the growth of that part of the branch operated on, and to check the flow of sap to the section in which the egg is laid.

These operations are distributed, in northern Illinois, over the month between the middle of June and the middle of July. The eggs hatch within a week or ten days, and the young larvæ penetrate the twig, burrowing downwards towards its point of attachment, and making holes to the surface at intervals thru which to discharge their excrement. After a time the larva cuts off, from within, the part of the twig thru which it has made its way, and plugs the open end of the burrow with coarse bits of frass. It occasionally repeats this plugging, pursuing its way until winter overtakes it, and pupating within its burrow from the middle to the latter part of the following May, first, however, commonly cutting off the branch obliquely and plugging the cavity a little beyond its pupal cell. (Fig. 50, 51.) The adult emerges during the latter



Fig. 50. Dogwood Twig girdler, *Oberea tripunctata*, larva. About 4 times natural size.

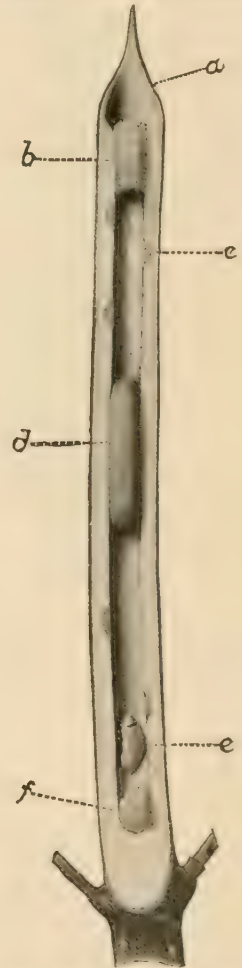


Fig. 51. Cornus twig with burrow of Dogwood Twig-girdler, *Oberea tripunctata*: *a*, end obliquely cut off by larva; *b*, *f*, plugs of frass; *c*, openings made by larva and plugged up later; *d*, cocoon of ichneumonid parasite; *e*, remains of parasitized *Oberea* larva.

half of June, eats its way thru this terminal twig, and feeds during its short life on the leaves of the infested tree, making oval holes thru the leaves along the course of the veins. (Fig. 53.)

The presence of this borer is commonly first betrayed by a withering of the leaves at the tip of the girdled shoots. It is a rather common pest in the Chicago parks, where it has often been abundant enough on the red-osier dogwood (*Cornus sanguinea*) to be decidedly injurious. Like the other small twig-girdlers, this species can best be destroyed by cutting off and destroying the affected



Fig. 52. Dogwood Twig-girdler, *Oberea tripunctata*, pupa. About $2\frac{1}{2}$ times natural size.

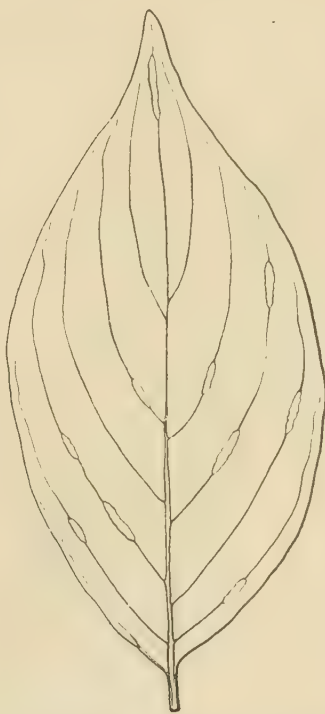


Fig. 53. *Cornus* leaf injured by feeding of adult Dogwood Twig-girdler, *Oberea tripunctata*.

branches at a time when they are certain to contain the borer; that is to say, in this case, in any month except June and July.

The various species of this genus have been so imperfectly distinguished that a specific description of this will not be attempted here; but the reader is referred to the illustrations for its general characters. Its larva is much subject to destruction by parasites; and a characteristic parasitic species has been repeatedly bred by us from infested twigs.

THE LOCUST BORER

(*Cyrtene robiniae* Forst.)

A great obstacle to the growth of the common black locust as a timber tree in Illinois has been the work of a borer which infests this tree only, multiplying year after year in a locust grove until it destroys every tree. It was a common practice in the early settlement of the northern part of the state for the farmers to plant a grove of locusts, with a view especially to a supply of fence-posts. These groves were, however, all destroyed by this borer during the middle part of the nineteenth century, and the planting of this tree was universally abandoned at that time. Of course, with the disappearance of the tree the borer likewise disappeared, and the growing of the locust is now again possible if due precautions be taken against its destruction by this insect. Fortunately, the recent work of Dr. A. D. Hopkins, in charge of forest insect investigations for the United States Department of Agriculture, has made it perfectly feasible to grow locusts with little or no loss from this cause, and the following account is mainly taken from his publications on this subject.

The first evidence of attack by this borer in spring is a fine brownish dust and an oozing of sap from the bark. Later, gumlike exudations appear on the injured spots, and quantities of yellowish

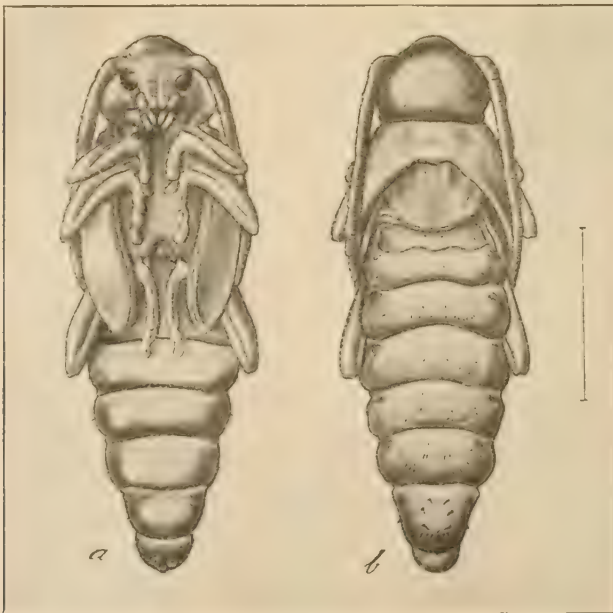


Fig. 54. Locust Borer, *Cyrtene robiniae*, pupa: *a*, front view; *b*, back view. Enlarged as indicated. (U. S. Dept. of Agriculture.)

dust lodge in the forks of the tree or branches, and in the loose bark on the trunk and around its base. Badly infested trees show a dwarfed, faded, or sickly foliage about the middle of May, and many of the leaf buds fail to open. The author of this injury is a whitish, thick-bodied, distinctly segmented, seemingly footless grub, nearly an inch long when full grown, with small head, and only a pair of minute feet on the next segment behind. It hatches from eggs laid in crevices of the bark from August to October. The young borers are still very small when the winter overtakes them, and they hibernate in small cavities made by them in the outer bark of the trunk and branches. They commence operations when the sap of the tree begins to flow the following spring, and presently penetrate the wood, burrowing actively about until July or August, in central Illinois, when they begin to change to the pupa (Fig. 54), to emerge about a month later in the beetle stage (Fig. 55).

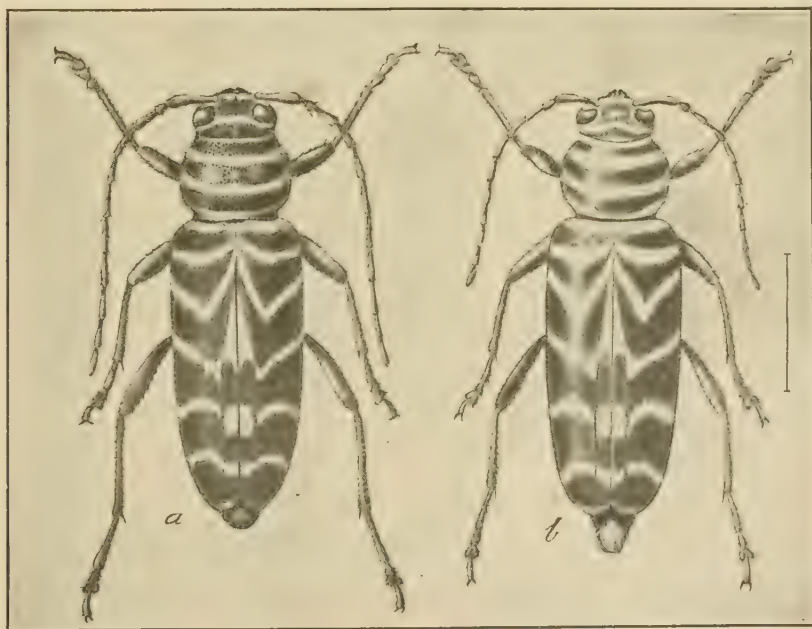


Fig. 55. Locust Borer, *Cyllene robinia*: a, male; b, female. Enlarged as indicated. (U. S. Dept. of Agriculture.)

The adult is a very showy, elongate, brown beetle, five-eighths to three-fourths of an inch in length, conspicuously marked with three straight bands of bright yellow across the thorax and five broken or irregular bands of the same color across the wing-covers. There is also a bright yellow patch on the upper side of the tip of the abdomen. The beetles are to be found in September, and occasionally in early October, on locust-trees, and on various species of golden-rod, upon the flowers of which they feed. Now and then a speci-

men may survive the winter and be taken abroad in April, or even in May.

From the foregoing statements it is evident that the time of cutting trees, whether to thin the grove or for commercial use, is an important item in the control of this beetle. All such cutting should be done between October 1 and April 1, care being taken that all trees showing the presence of the borer are selected for removal. The bark should then be taken off, and the brush and rubbish should be burned. Simply to kill the larvæ and borers in badly infested and damaged trees, these should be cut and destroyed in May and June, when their condition can be readily detected; but the work should be completed by the time the flowers have all fallen from the trees, as otherwise the borers may mature and escape. Where the beetles are abundant on the goldenrod, they may be attracted and killed, according to Dr. A. D. Hopkins, by smearing molasses poisoned with arsenic upon the trees, due account being taken of the fact that honey-bees are liable to destruction by this poison, and that it should not be used where these are kept. Unsuccessful experiments were made by one of my assistants, Mr. W. P. Flint, in 1910, with a mixture of sugar and vinegar, and another of sugar and alcohol. Altho attractive to a variety of other insects, the beetles of the locust-borer paid no attention to them. Tanglefoot, on the other hand, placed on the trees September 16, when the beetles were freely running about mating and laying their eggs, disabled the beetles and put a stop to their operations.

Highly useful directions for the management of locust plantations in a way to prevent injury by borers, are contained in Bulletin 58 of the Bureau of Entomology of the U. S. Department of Agriculture, printed in 1910.

THE OAK TWIG-PRUNER (*Elaphidion villosum* Fabr.)

Among the more striking and curious kinds of insect injury to trees are those which take the form of amputation of twigs and small branches during the growing season—an injury which seems purposeless and excessive until one sees just how it benefits the author of it.

The oak twig-pruner (Fig. 56) is one of the best known American insects with this habit of injury, affecting, as it does, a large variety of trees and shrubs, and injuring most frequently some of the commonest and most useful species. It is best known, perhaps, for its work on oaks, hickories, and maples, altho it has been reported to attack also apple, peach, pear, plum, quince, locust, redbud, sumach, Osage orange, fir, grape, and climbing bittersweet. In Illinois we have bred it from oaks, hickories, persimmon, and peach,

and have found it thruout the state. In parts of Michigan, peach-trees have sometimes been nearly destroyed by it, and an equally serious injury has been done by it in New York to pears. In Illinois we once found it at Effingham cutting off young apples-trees from



Fig. 56. Oak Twig-pruner, *Elaphidion villosum*, larva.
About 5 times natural size.

one to two feet above the ground; and Dr. F. W. Goding reported it, in 1884, as doing great damage to hickory and elm at Ancona, in Livingston county. In Pennsylvania, oak forests have been so infested by it that carloads of the twigs might have been collected from under the trees; and in Connecticut, hickories have been so thoroly pruned that a barrel of twigs and branches have fallen from a single tree.

The injury done by this insect is not, however, so severe as it looks. It may affect considerably the appearance of young trees, by deforming their top; but large trees are generally little harmed by the pruning they receive, and the littering of lawns with amputated twigs is at most an annoyance merely. The girdled twigs and branches may vary in length from a few inches to several feet, but Dr. Fitch mentions one that was ten feet long and over an inch thick. Commonly, however, they are a quarter of an inch or less in diameter, and vary from two to six inches in length. Occasionally a single one will contain two larvæ, the burrows then running down each side of the twig. Fallen limbs, if not disposed of, may serve, as Chittenden has said, as breeding places for various kinds of injurious borers, which may come out from them to attack and injure living trees.

The method of the pruner's work is such that a fallen twig is seen to have been hollowed out centrally—a large part of its interior often being eaten away—and plugged with sawdust, and its larger end has been gnawed off from within, having a cut surface as smooth as if made by a chisel.

The adult twig-pruner is a rather slender, dark brown beetle (Fig. 57) from a half to three-quarters of an inch in length, sparsely covered with coarse white or yellowish hairs which show a tendency to collect in irregular clumps or spots. The edge of the tip of each wing-cover is concave between two stout sharp spines or teeth, of which the outer is usually the larger. The female lays

her eggs in the smaller twigs of living trees, most commonly in July. The young larva first eats out the wood under the bark in the direction of the grain, packing its burrow behind it with its castings, and working towards the base of the twig. Later it cuts holes in the bark thru which these castings are rejected, and then follows the center of the twig, making a channel more or less oval in cross-section, corresponding to its own shape. When it has reached its growth it begins to gnaw, from within, a circular groove, deepening this until the twig or branch is so weakened at this



Fig. 57. Oak Twig-pruner, *Elaphidion villosum*, adult. About 5 times natural size.

point that the wind readily breaks it off, usually carrying the insect with it. Occasionally, however, the larva is left in its burrow on the tree and finishes its transformations there. The value of this operation to the pruner would seem to be a preparation for the exit of the beetle, which originates within the burrow, but which has not jaws of a sufficient strength to enable it to gnaw its way out thru the wood inclosing it. This explanation, given by Chittenden, seems at least to be the most reasonable among several that have been proposed to account for this curious habit. After the twig has been cut off the larva within it plugs up the severed end, changes to the pupa, and later to the beetle, coming out as an adult the following summer.

Published accounts disagree as to the length of the life cycle of this species. It seems to be a single year under the most favorable conditions, but capable of being lengthened to two or even three years, particularly if the branch dies before the larva is full grown.

As nearly all the borers pass the winter in the fallen twigs, it easily follows that their injuries may be readily arrested by gathering these up and burning them in winter or in spring. This effective measure is so simple and so easily applied that no other seems necessary.

THE BRONZE BIRCH-BORER

(*Agrilus anxius* Gory)

This insect is a deadly pest of the birches, especially of the beautiful and popular white birch, which it is quite capable of exterminating locally if its presence is not early detected and if prompt measures are not then taken for its destruction. As an infested tree is not likely to last more than two or three years, the necessity of energetic measures is obvious. Unfortunately, this insect does not usually make conspicuous local marks of the injury it is doing, and the earliest sign of its presence is often the death of one or more branches in the top of the tree. If a birch is seen to be dying at the top it should at once be examined for evidences of the presence of this borer, since in some cases this condition may be due to drought or other general causes. If the bronze borer be the cause, the fact may be ascertained by lifting the bark from dead branches which are not yet dry, or from the more unhealthy looking spots on the living parts of the tree. If the insect be present, its tortuous or zigzag burrows will be noticed, and further search will disclose the borer itself in one or more of its stages of larva, pupa, or adult. Sometimes, indeed, its presence is shown by a ridged appearance of the bark, the ridges running crosswise of the branches or in a more or less spiral direction. Peculiar rusty or reddish spots may also be seen on the larger branches or on the trunk where the bark has been undermined by the interlacing burrows of the borer. Often branches weakened by the borers and by consequent decay of the wood, break at the point of injury, either hanging down or falling from the tree. This appearance is rather characteristic of the work of the borers, and may serve to distinguish an infested tree from a "stag head," due to drouth.

In its destructive stage this insect is a small, flattened, footless, creamy white grub about three-fourths of an inch long when full grown, with dark mouth-parts and a small head which is partly drawn back into the broad, flat, pale brownish, first segment of the body. At the opposite end is a pair of minute forceps-like spines, brown and hornlike, with two teeth on the inner edge of each. In this larval condition the borer may be found in its burrows beneath

the bark at any time during fall, winter, and early spring. If the tree has been long infested, the bark is usually perforated by small roughly semicircular holes about twice the diameter of the head of an ordinary pin. (Fig. 58.) These holes are made by the beetles when they come out in May and June for their brief life in the open air.

The beetle (Fig. 59) is a hard, small, bronze-green or violet insect, varying somewhat in size, but approximately half an inch long or a little less. It is shining but minutely punctured under a glass,

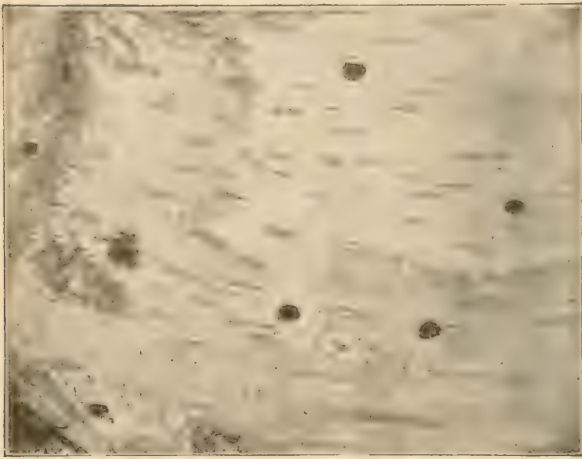


Fig. 58. Exit holes of the Bronze Birch-borer, *Agrilus anxius*, in the bark. Natural size. (Cornell Experiment Station.)



Fig. 59. Bronze Birch-borer, *Agrilus anxius*, adult. About 5 times natural size.

with the sides nearly parallel, tapering conspicuously behind to a blunt tip, notched where the rounded ends of the wing-covers come together.

Altho most notorious for its injury to the white birch, especially the cut-leaved variety, it infests all the birches. It is the most destructive enemy of these trees in the Chicago parks, thru which it is generally distributed. It is especially dangerous because there is no means of destroying it which does not involve also the destruction of the infested tree. It is a saddening conclusion which is forced upon the owner of a beautiful birch infested by this borer, that the tree is doomed, and that the only means of saving other trees in its neighborhood is to cut it close to the ground in winter or spring, as early as the first of May, and to burn it, trunk and branches, before the beetles can emerge to lay their eggs elsewhere.

The larvæ hatch in June, and possibly also in July, from eggs laid in crevices in the rougher places of the bark. They bore thru the bark at once and begin to mine in the sapwood, sometimes dipping inward to the older wood or even penetrating to the center of a small branch. The irregular mine is always packed with the castings of the grub, and increases in diameter, of course, as the latter grows, measuring at the largest about an eighth of an inch across. Here the borer lives in the larval state until the latter part of the following April or early May, when it begins to transform within its burrow to the pupa stage, and within another month to the beetle. This escapes from the tree from the middle to the last of June in northern Illinois, by gnawing through the bark, flies abroad to feed on the leaves of trees, and soon pairs and lays its eggs. Curiously, it seems to feed but little on the birch, preferring the leaves of poplar, willow, and elm to those of its native tree. There is, indeed, some evidence that it infests the willow, producing gall-like swellings on the twigs, but the identity of the species to which this injury is referred is not positively settled.

Trees of large size are often killed by this borer within three or four years after they first become infested, and few live more than two or three years after the top branches begin to die. The necessity of prompt action is thus manifest, and as the time of the escape of the beetles varies with latitude and the weather of the year, it is best to take time by the forelock and to destroy the infested tree as early at least as April 1. Then one may be sure that nothing can have escaped from it to extend the injury.

This insect is not now known to range beyond Virginia to the south or Illinois to the west, but it very likely occurs wherever birches are grown. We have lately found it (1910) outside Chicago, in Elgin, Rock Island, Moline, and Bloomington, abundant enough in all these places to be decidedly injurious to the birches. It has been quite fully discussed by Professor M. V. Slingerland in Bulletin 234 of the Cornell University Agricultural Experiment Station, published in January, 1906, and briefer accounts may be found in the report of Dr. E. P. Felt, State Entomologist of New York, in "Insects Affecting Park and Woodland Trees" (page 284), published in 1905; in an article by F. H. Chittenden published in 1898 in Bulletin 18, new series, of the Division of Entomology, U. S. Department of Agriculture; and in a paper on "A Disease of the White Birch," by John Larsen, printed by the Michigan Academy of Science in its third report (1902).

THE SCURFY SCALE

(*Chionaspis furfura* Fitch)

The so-called scurfy scale is the commonest of all scale insects thruout the state on shade and orchard trees. The female scale

(Fig. 60, *a*, *c*) is about a tenth of an inch in length, irregularly oval, with a yellowish point at one end, and but very slightly convex. It is nearly white when fresh, but becomes gray or sooty with exposure. The scale of the male insect (Fig. 60, *b*, *d*) is

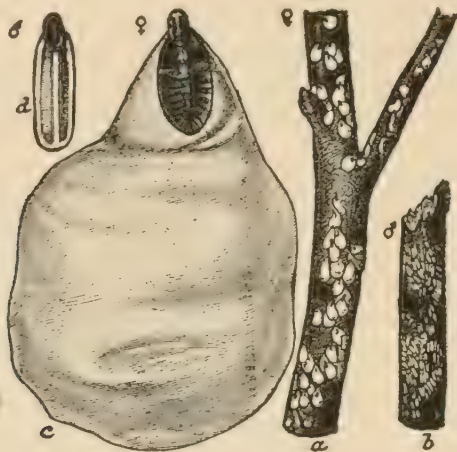


Fig. 60. Scurfy Scale, *Chionaspis furfura*:
a, *b*, female and male scales, natural size; *c*,
d, same, enlarged.

narrow, with sub-parallel sides, and is marked by three longitudinal ridges. The species may be readily recognized in winter by the fact that under each female scale will be found a small mass of minute, purplish eggs. The young appear to the naked eye as active, snowy whitish or reddish specks. These insects are often so abundant on an infested tree as to give a scurfy appearance to the trunk and limbs.

This scale insect is a general feeder, but is especially common on rosaceous plants. It also heavily infests the elm, which seems the most susceptible to its injuries of any of our ordinary shade trees. The red-twigged dogwood is often incrustated by it, and the mountain ash, hawthorn, pear, and currant are sometimes attacked. The scurfy scale winters in the egg, and hatches, with us, during the latter half of May—earlier or later according to the season and the part of the state. In central and southern Illinois eggs are laid for a second generation, the date of which, however, has not been accurately determined. Altho this can not be classed among the more destructive scale insects, it is nevertheless injurious where especially abundant, checking the growth and diminishing the vitality of the infested tree or shrub in a way to make it less presentable and more susceptible to the attacks of other insects and of disease.

Two insecticide sprays are fairly effective against this insect; one a winter spray of lime and sulphur, prepared and administered as described in detail under the article concerning the San Jose scale, and the other a summer spray of kerosene emulsion, a formula

for the preparation of which is given under the cottony maple scale. The lime-sulphur mixture should be applied as late in the winter as practicable, best just before the opening of the leaves in spring. The kerosene emulsion must be applied immediately after the hatching process is virtually complete, a point which can only be determined accurately by careful observation. If the young are allowed to live too long they become covered and protected, after fixing themselves, by a waxy scale which the emulsion will not penetrate. It should be applied in a strength to contain ten percent of kerosene. Dr. James Fletcher, Dominion Entomologist, Canada, recommended spraying infested trees with a whitewash made by slaking a pound of lime to the gallon of water, one such application to be made in fall as soon as the leaves have fallen, and a second immediately after the first has dried. This is said to loosen the hibernating scales, which subsequently fall from the tree with the dried whitewash.

THE OYSTER-SHELL SCALE

(*Lepidosaphes ulmi* Linn.)

The oyster-shell scale is among the more conspicuous and easily recognized of the smaller scale insects of our trees and shrubs, the

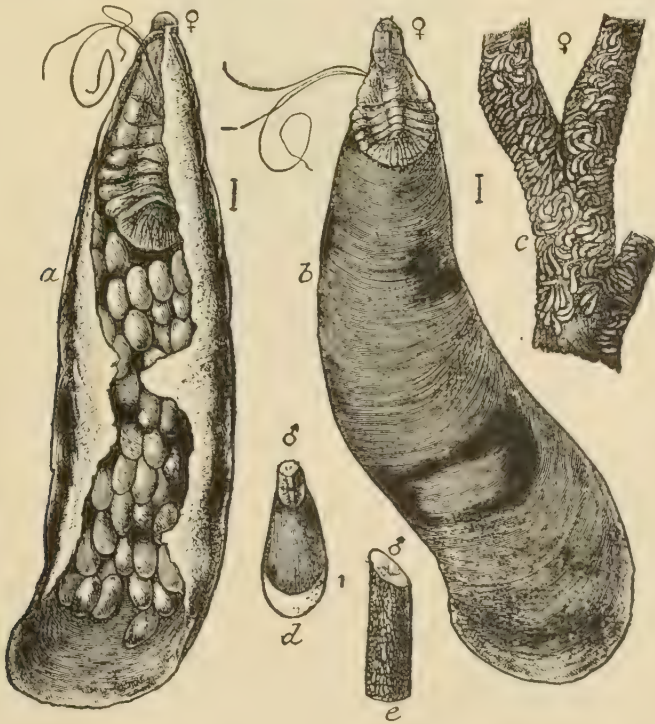


Fig. 61. Oyster-shell Scale, *Lepidosaphes ulmi*: a, female scale, under side, showing insect and its eggs within; b, same, from above; c, same, natural size; d, e, male scale, enlarged and natural size.

common name suggesting its most conspicuous character. It has, indeed, the convex, elongate, and more or less bent and irregular form of an oyster shell. The female scales (Fig. 61, *a, b, c*) are about an eighth of an inch long, the male scales (Fig. 61, *d, e*) smaller, with a little hinge or flap behind, thru which the winged males escape when mature. The scale is usually brown to dark brown in color, tho occasionally bleached to gray by exposure to the winter weather. The eggs of the species hatch in Illinois shortly after the time the apple blossoms fall. Each female scale has during the winter from fifty to a hundred and twenty-five pale yellowish eggs beneath it, from which the young emerge during the latter part of May or the first of June. A second generation occurs in central and southern Illinois early in July. The young are able, at first, to crawl about somewhat actively, and it is principally by this means that the species is distributed, altho it may be conveyed to distant points upon infested nursery stock. The scale insect is both larger and more injurious than the scurfy scale, and infests also a larger variety of trees and shrubs. Elm, poplar, willow, horse-chestnut, lilac, red-twigged dogwood, and currant are among those most frequently and seriously injured.

The treatment for this scale is identical with that described in the article for the scurfy scale, just preceding.

THE SAN JOSE SCALE

(*Aspidiotus perniciosus* Comst.)

This notorious and destructive pest is much less injurious to ornamental vegetation than to fruit trees and shrubs, but is nevertheless decidedly harmful to several of the former, particularly to those belonging to the family of roses. It is also very injurious to the mountain ash, but the Japanese quince (*Pyrus japonica*) is the common shrub most likely to betray its presence.

It is a circular, grayish or yellowish, scale insect about one-sixteenth of an inch in diameter, but slightly convex, and marked by a central nipple and one or two surrounding circular ridges. It is an inconspicuous object, but is recognizable by the appearance which it gives to a badly infested bark (Fig. 62), which it covers with dark gray patches of a continuous grayish crust, which exudes, when crushed with the finger-nail, an oily, yellowish substance due to the pressure on the living insects under the scales. The bark of a tree but sparsely infested may be seen, on close examination, to be irregularly specked with small circular granules which give it an unhealthy look. The surface immediately beneath the living scales often shows a reddish discoloration; and on the leaves and green twigs are more conspicuous red blotches which surround the scales.

The largest scales are about the size of the head of an ordinary pin, and the smallest ones are mere specks on the twig.

This insect passes the winter partly grown, reaches its full size in spring, and begins to bring forth its living young about the first of June, in average years, in the central part of Illinois. These may be seen as minute yellow specks wandering over the surface in search of a suitable place to establish themselves. This period of active life is often limited to a few hours, and at most to one or two days. Three or four generations are bred in a single season.

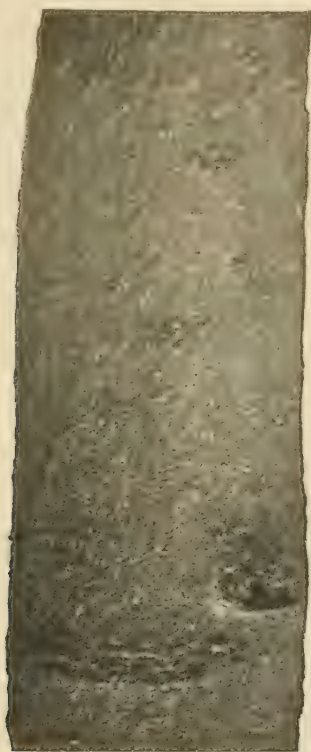


Fig. 62. San Jose Scale, *Aspidiotus perniciosus*. Natural size. (Connecticut Experiment Station.)

It has been found commonly infesting and often injuring more than seventy trees and shrubs, and occasionally nearly as many more. The commoner kinds coming under the former list are some of the dogwoods, the hawthorns (*Crataegus*), the quinces, the poplars, the cherries and pears, currants and gooseberries, roses, willows, mountain ash, snowberry, lilac, basswood, Osage orange, and the elms. Those less seriously infested are the maples, horse-chestnut, Virginia creeper, the birches, chestnut, catalpa, hackberry, the flowering and other dogwoods, the persimmon, *Forsythia*, white ash,

honey-locust, *Althea*, pecan, black walnut, mountain laurel, honeysuckle, mulberry, white spruce, sour cherry, sumach, smoke-bush, locust, raspberry and the blackberry, elder, sassafras, various species of *Spiraea*, arbor-vitæ, *Iiburnum*, and grape. Popular species not infested by it are *Ailanthus* or tree of heaven, papaw, spice-bush, barberry, trumpet-vine, the hornbeams, cedar, bittersweet, buttonbush, Judas-tree, fringe-tree, pepperbush, leatherwood, gingko, Kentucky coffee-tree, witch-hazel, English ivy, hickories except the pecan, hydrangeas, yellow jasmine, butternut, juniper, larches, sweet gum, tulip-tree, matrimony-vine, wax myrtle, black gum, syringa, pine, sycamore, the oaks, the rhododendrons, bald cypress, trumpet-creeper, blueberry, hemlock, *Wistaria*, and prickly ash. The last list is especially important in Illinois, thruout which the San Jose scale is certain ultimately to become generally distributed, because it includes a large and varied list of ornamentals from which selections may be made without the risk of loss or injury by this most destructive pest.

The San Jose scale is conveyed to distant points mainly by the trade in nursery stock, and otherwise it spreads only by means of the minute crawling young. Its means of dispersal are so slight that it tends to concentrate upon any tree infested until the latter becomes completely covered by it, a fact which, taken together with its numerous generations, its rapid rate of multiplication, and its freedom from parasites capable of overcoming it, make it the dangerous enemy which it has become.

The San Jose scale can be destroyed by the winter use of one of the lime and sulphur mixtures, which may either be purchased ready-made in condition for use by dilution only, or may be brought into solution by boiling the raw materials together according to the following directions.

Materials: 15 pounds of lime, 15 pounds of sulphur, and 50 gallons of fairly soft water. For 50 gallons of the spray, heat 12 gallons of water in a 40-gallon iron kettle, mixing, in the meantime, in a separate vessel, 15 pounds of sulphur with enough water to form a thin paste. Add this sulphur to the water in the kettle and bring the mixture to a temperature just below boiling. Then add 15 pounds of best lump lime, keeping cold water at hand to use as the mixture threatens to boil over. After the lime is fully slaked, boil for 40 minutes, with almost constant stirring. Then strain into a 50-gallon spray-tank and fill with water, which had better be warm, although cold water will do. To prepare 100 gallons of the spray at a time, heat 20 gallons of water in the 40-gallon kettle, add 30 pounds of sulphur—previously reduced to a thin paste with water—and to this put 30 pounds of lime. Boil as before, and dilute to 100 gallons.

If a supply of steam is available for cooking the mixture, this will be found a much more convenient source of heat. The cooking is then done in barrels or other vessels, from which the fluid is strained into the spray-tank. The disturbance caused by the introduction of steam makes stirring unnecessary. When cooked with steam the mixture does not ordinarily become so dark as when boiled over a fire, but the insecticide effect is nevertheless the same.

PUTNAM'S SCALE
(*Aspidiotus ancylus* Putnam)

This is a circular or oval, dark gray or black, scale insect, about one-twelfth of an inch in diameter, with a brick-red point at one side of the center. It closely resembles the San Jose scale in general appearance, but does not present the conspicuous ring and nipple structure of the latter, altho the young have usually a nipple and a rather indefinite ring.

It passes the winter but partly grown, but differs from the San Jose scale in the fact that it reproduces by means of eggs laid in late spring or early summer. There is but one generation in a season.

It has been found on elm, willow, oak, hemlock, mountain ash, *Ilex*, white birch, *Prunus*, ash, beech, hackberry, linden, maple, Osage orange, and water-locust. It is rarely injurious enough to require special attention.

THE WALNUT OR WILLOW SCALE
(*Aspidiotus juglans-regiæ* Comst.)

This species, altho common on a number of shrubs and shade trees, is of little importance except on the willow, to which it is a veritable pest. It is easily distinguished from other scales of the San Jose relationship by its relatively large size, its diameter being 3 mm., or an eighth of an inch. The female scale (Fig. 63, *a*, *c*.) is

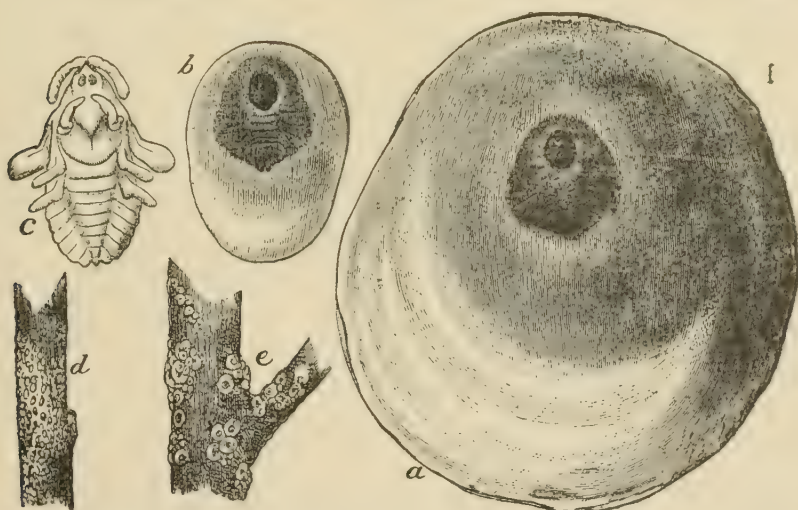


Fig. 63. Walnut Scale, *Aspidiotus juglans-regiæ*: *a*, *b*, female and male scales, enlarged; *c*, male pupa; *d*, *e*, male and female scales, natural size.

circular, flat, with a prominent pink or reddish point at one side of the center. The male scale (Fig. 63, *b*, *d*) is elongated, with a corresponding point near one end. The female passes the winter as an adult, and lays her eggs in early spring.

Treatment the same as that for the scurfy scale.

THE COTTONY MAPLE SCALE

(*Pulvinaria vitis* Linn.)

The cottony maple scale (Fig. 64) is one of the best known scale insects because it heavily infests several very common shade trees, and because the cottony masses beneath the body of the adult female in early summer make it a very conspicuous object. These large white masses are a deposit of waxy threads within which are the minute, oval, pale yellowish eggs.

The history of this insect in Illinois since 1867 exhibits successive periods of abundance and of scarcity, each averaging about four or five years for the state as a whole. That is, thruout some considerable part of the state, and often over most of it, the maple scale has been injuriously abundant once in eight or ten years, and its period of abundance has lasted, as a rule, about half this time. In any given locality, however, it has usually been injurious for a much shorter time, often for not more than one or two years. The cessation of its injuries and its virtual disappearance from the trees infested by it have seemingly been due almost wholly to the agency of its insect enemies.

The soft maple (*Acer saccharinum*) is the tree most generally and heavily infested by this insect. The hard maples, on the other hand, are infested but slightly if at all. The box-elder is also greatly subject to injury, and next to this, perhaps, the linden or basswood. Among the other trees and woody plants often more or less injured, are the elm, honey-locust, black locust, black walnut, sumac, willow, poplar, beech, hawthorn, bittersweet, grape-vine, and Virginia creeper. We have found mature egg-laying females on the horse-chestnut, honeysuckle, dogwood, trumpet-creeper, mulberry, snowberry, smoke-tree, *Spiraea*, false syringa (*Philadelphus*), and *Histaria*. Oak, ash, and catalpa are not infested in northern Illinois, but injury to oaks is reported from Georgia. The pear is said to be most liable to injury among the fruit trees, and apple, plum, and peach are sometimes infested. Serious damage to fruit trees is, however, very unlikely. The migrating young, which are often washed from trees by rain, or blown off in considerable numbers, may maintain themselves for a time on a great variety of woody and herbaceous plants, those on the latter, of course, perishing with the advent of frosts.

In early summer this scale, when very abundant, coats the under side of heavily infested limbs with a thick layer of cotton-like waxy masses, each projecting from beneath a brown cap or scale—the flat body of the mature female. This “cotton” is secreted and the eggs are deposited within it in late May or early June in the latitude of central Illinois, but usually one or two weeks later in the Chicago district.

Something over 3,000 eggs are usually laid by each female, the number ranging, in our counts, from 2,856 to 3,863, with an average



Fig. 64. A Soft maple twig badly infested with adults of the Cottony Maple Scale, *Pulvinaria vitis*. About natural size.

of 3,410. In central Illinois the eggs ordinarily hatch in June, and in the northeastern part of the state in early July, or later if the weather of the time is unfavorable. Virtually all are hatched, as a rule, by the end of July.

When first hatched the six-legged young (Fig. 65, *a, c, f*) move slowly about as creeping yellowish specks about twice as long as wide. They soon settle upon the leaves, mostly upon the under side

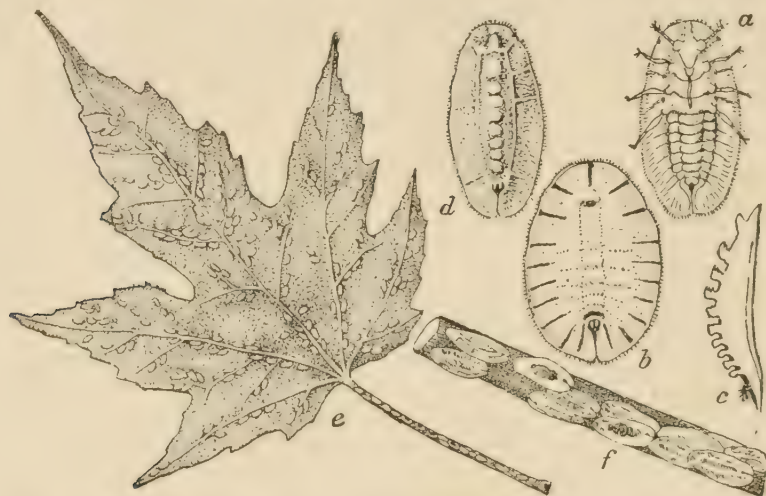


Fig. 65. Cottony Maple Scale, *Pulvinaria vitis*, immature stages: *a*, newly hatched young, under side; *b, c*, young female, top and side views; *d*, young male; *e, f*, young on leaf and leaf stem. Natural size shown in *a*.

along the veins, but a considerable percentage also on the upper surface. Soon after settling down, a thin waxy layer forms on the back, and in about three weeks the insect has virtually doubled in size. As they increase in size the male and female scales become distinguishable (Fig. 65, *b, c, d*) by the fact that the former are comparatively narrow and more convex. From these the winged males (Fig. 66, *a, b, c*) emerge to fertilize the stationary females in August and September, perishing soon thereafter. In autumn the young females migrate from the leaves, which are about to fall, to the twigs, upon which they pass the winter and, indeed, the remainder of their lives. In spring the female scale (Fig. 67) is elliptical, convex on the back, with a low, rounded, median ridge. It is pale greenish or whitish yellow, marked with black or dark brown. When full grown, about the middle of May, it is 4 to 6 mm. long and 3 to 4.5 mm. wide. Its body is at first closely applied to the surface of the twig, but with the development of the eggs beneath it the abdomen is gradually raised from the bark to an angle of forty-five degrees or more.

It is usually difficult to say whether trees infested by this insect should receive special treatment, or whether they may be safely left

to the natural course of events. The cottony maple scale is extremely subject to parasites and attacks of other insect enemies, particularly to the black hemispherical ladybugs and their larvæ, the latter of which feed upon the egg masses in spring and summer. With an extraordinary abundance of the scale insects themselves

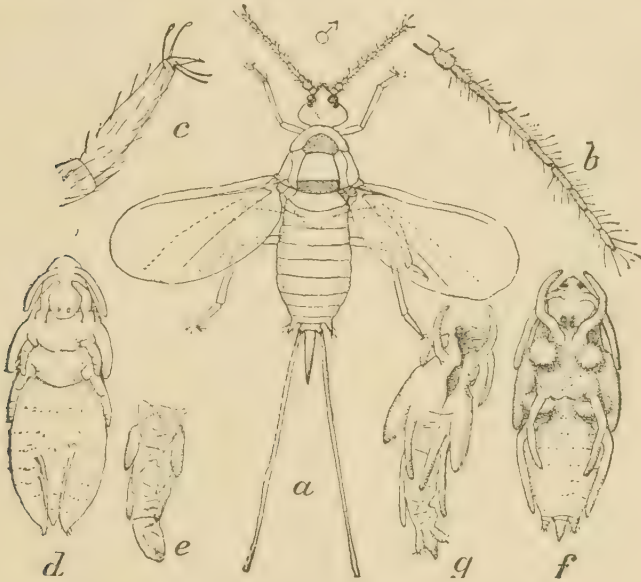


Fig. 66. Male of Cottony Maple Scale, *Pulvinaria vitis*: a, adult; b, c, antenna and leg enlarged; d, e, second stage of pupa and its cast skin; f, g, true pupa and its cast skin. All greatly enlarged.

these insect enemies improve the opportunity for unusual multiplication in a way to produce a greater number than can possibly be maintained permanently by the scale insects. A check is thus put upon the increase of the latter which, within a few months, may reduce them to insignificance. The consequence is an irregular peri-

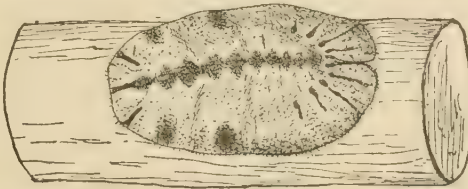


Fig. 67. Cottony Maple Scale, *Pulvinaria vitis*. Adult female in spring, just before the formation of the cottony egg sac. Enlarged.

odicity in the numbers of the cottony maple scale such that two years of injurious abundance rarely succeed each other in the same place. Nevertheless, where trees are evidently suffering from the scale attack it is always prudent, and often necessary, to take artificial measures of protection.

As the newly hatched young are especially susceptible to the petroleum insecticides, which act by contact, a definite knowledge of the hatching period has an important practical value. In central Illinois this period extends approximately from June 15 to July 20. In and about Chicago it commonly begins about two weeks later, and continues for a period of three weeks, this retardation being apparently due to the higher latitude and to the neighborhood of Lake Michigan. The period varies, in short, as to its beginning time, with the advancement of the season, and once begun, the rapidity of the hatching will depend, other things being equal, on the warmth of the weather. It is also influenced locally by the amount of foliage on the trees, the eggs hatching later and more slowly in a dense tree-top than in one more open to the sun.

The only insecticides available against these insects are those which kill by contact, and of these the kerosene mixtures have thus far been found the most useful. Even these can be applied only to the young scales shortly after they hatch from the egg, no insecticide treatment being available for the destruction of the large and conspicuous females upon the twigs in May and June. The common kerosene emulsion, made by thoroly and intimately mixing kerosene with one-third of its volume of a strong soapsuds, is a satisfactory spray when diluted to contain ten percent of kerosene for summer use, and sixteen to eighteen percent is used in winter. As a summer spray this emulsion must be used twice in succession, once when about half the eggs are hatched and again about ten days thereafter. A single treatment in winter is about the equivalent in practical effect of two such summer sprays. Large trees in a sandy soil, and especially those in more or less unthrifty condition, should be guarded against possible injury to the roots from the dripping of the kerosene spray, or from that part of it which may run down the trunk and so reach the earth. For this purpose it would be well to cover the ground before spraying with a thin layer of straw, packed closely around the base of the trunk, and later to gather this up and carry it away.

The cost of materials for large trees will average approximately fifteen cents a gallon for the summer spray, and about twice as much for the winter strength.

Kerosene emulsion is made as follows: Dissolve one pound of common soap, or half a pound of whale-oil soap, in one gallon of water by boiling, remove from the fire, and add two gallons of kerosene. Then with a spray pump force the mixture back into itself for about five minutes, or until it presents the appearance of a thick cream and no longer separates on standing. This is the undiluted emulsion. For a mixture containing ten percent of kerosene, add seventeen gallons of water to the three gallons thus prepared. For

an eighteen-percent kerosene emulsion, add eight gallons of water to the stock emulsion. Soft water is to be preferred.

The following tables will show the effects of kerosene sprays as applied by us in 1905 and 1906.

SUMMER SPRAY

Treatment		No. of trees	Leaves examined	Scales examined	Percent killed by spray
Insecticide	Part of hatching period				
10 percent kerosene.....	Beginning	1	75	48,789	33
10 percent kerosene	Middle	1	50	19,425	64
10 percent kerosene	End	3	150	281,271	68
10 percent kerosene.....	Middle and end	1	100	57,179	82

WINTER SPRAY

When sprayed	Percent of kerosene	Date of counting	Scales counted	Percent killed
December 26 to January 5 (once).....	19	Feb. 1	12,703	86
January 11 to 13 (once).....	20	Feb. 1-2	23,061	91
January 11 to 13 and March 30 (twice).....	19-24	June 10	48,395	91

MISCELLANEOUS ECONOMIC INSECTS

BY CHARLES A. HART

THE HEART-WOOD BORER

(*Parandra brunnea* Fabr.)

Parandra brunnea is a shiny chestnut-brown, parallel-sided beetle (Fig. 2, 3) about five-eighths of an inch to three-quarters of an inch long and a quarter of an inch or less in width. It belongs to a small family (*Spondylidae*) closely related to the long-horn borers (*Cerambycidae*) and of similar habits. The larva is a wood borer about an inch long (Fig. 4), resembling the common round-headed borers except in the strong forward slope of the thorax and the small low-set head.

A variety of observations made by the writer during a number of years seems to indicate that the heart-wood borer, altho generally supposed to feed only on dead wood, is a much more important and destructive pest of fruit and shade trees than the scanty references to it in economic literature would indicate, and the published and observed facts about the species are therefore here brought together.

PUBLISHED DATA

In the *American Entomologist* for January, 1880, Dr. C. V. Riley acknowledged, from Shelby Reed, of Scottsville, N. Y., samples of a borer said to affect badly the roots of black ash trees in New York to such an extent that it was killing out these trees in parts of the state. The larva sent was new to Dr. Riley, and he asked for more specimens. In the number for August of the same year, a second letter from this correspondent is published, accompanied by more material illustrating the injury, including the adult, which was identified by Riley as *Parandra brunnea*. Riley answers that its larvæ are frequently found in dead or decaying wood of various trees, especially oak and beech, but are not known to attack healthy timber; and that from the evidence at hand the decay of the ash trees was apparently not primarily caused by the borer. He added, however, that there could be no doubt that the death of the trees was accelerated by the working of these larvæ, and that the species might therefore be considered injurious, especially when it occurred in such numbers as in the present case.

The observations of Mr. Reed, as detailed in his letter, agree closely with our observations, and are worth repeating. He says

that the tree breaks by wind pressure where most bored, usually near the ground, sometimes ten or twenty feet up; that the decay begins at the center and progresses outwardly; that, avoiding the outward shell and the inward mush, the larvæ feed where decay is incipient; that, as one of the sections plainly shows, if they venture too near the surface they fall a prey to the woodpeckers; that away from browsing live stock young ash seedlings remain healthy and plentiful; that this insect is most numerous in trees of full, mature



Fig. 1. Heart-wood Borer, *Parandra brunnea*, work of larva in base of soft maple in Urbana, weakening the base so that the tree fell during a high wind.

growth; and that exposure of the trunk to the sun hastens the increase of the insect.

Packard, in the Fifth Report of the United States Entomological Commission, says on the authority of Mr. Chittenden that the species has been taken under the bark of oak trees and is very common under the bark of cultivated cherry trees. Luggar says that in Minnesota it is very common under the bark of pine; and Gibson quotes Townsend as saying that it is found under basswood bark, and that it infests a variety of deciduous and coniferous trees.

Quite recently, Snyder* has reported this species as seriously injurious to chestnut telephone and telegraph poles, shortening their

*Bull. 94, Pt. 1, Bureau of Ent., U. S. Dept. Agr.

period of usefulness by burrowing into them not far above or below the surface of the ground; and Gahan* has added further details on the same injury.

The species has a wide distribution, ranging from the Atlantic coast westward to Arizona and southern California, and northward to Ontario, Canada.

DATA FROM OFFICE RECORDS

An apple tree on my place was blown down December 9, 1899, and its base was found honeycombed by larvæ. Infested portions were placed in a breeding cage, and beetles of *Parandra brunnea* emerged July 17, 19, and 21, and August 7.

When on the grounds of a large Illinois nursery near Springfield, August 27, 1904, my attention was called to large apple orchards which were being seriously injured by borers, supposed to be the



Fig. 2. Heart-wood Borer, *Parandra brunnea*, male at right, female at left. Very slightly enlarged. (U. S. Dept. of Agriculture.)



Fig. 3. Heart-wood Borer, *Parandra brunnea*, male adult.

common round-headed borer (*Saperda candida*). It was reported that the infestation had been evident since June, and that altho there were few pupæ in the wood at the time, they had been very common earlier in the season, up to about three weeks before. This agrees closely with the breeding of adults just mentioned. It was said that nearly all the old trees had been heavily infested, and several larvæ were found even in young nursery stock. The owner and his foreman agreed that the larvæ attacked healthy wood and even healthy trees, so that much damage was shown.

* Jour. Econ. Ent., Vol. IV, p. 299.

An examination of the trees showed numerous larvæ, with remnants of adults of *Parandra brunnea*. The attack seems to begin at the base, less commonly higher up on the trunk, and probably at some point of injury and decay. The larvæ then work upwards, especially about the central axis, into living heart-wood, which they riddle and cause to decay until the base is a mere shell. The riddled space is usually roughly conical in form.

A large soft maple tree about two feet in diameter on a street near the University of Illinois, had some large roots cut away close to its base to make room for a sidewalk. The exposed surface decayed, of course, and some years later, in August, 1907, the tree blew down. It was examined August 5 by Mr. J. D. Hood, who found the entire base honeycombed with burrows, this honeycombed

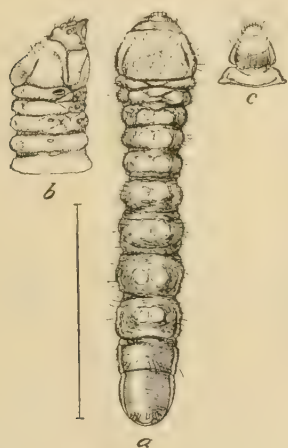


Fig. 4. Heart-wood Borer, *Parandra brunnea*; a, larva, enlarged as indicated; b, side view of its head and fore part; c, clypeus and labrum. (U. S. Dept. of Agriculture.)



Fig. 5. Heart-wood Borer, *Parandra brunnea*, pupa. Enlarged as indicated. (U. S. Dept. of Agriculture.)

portion extending upwards conically into the heart of the trunk. The newest burrows were evidently close to the outer sides of the cone, next to or in living wood. Adult beetles of *Parandra brunnea* were found in crevices in the broken end, and a number were seen flying near by at dusk. Another tree with a similar history is shown in Fig. 1.

An examination of the shade trees in various parts of Urbana shows very many trees in similar condition. There is a small cavity formed by the decay of an injured or amputated projecting root-head, and a slope of comminuted decayed wood in the opening, fallen from the workings above. On this one may occasionally see a red-brown wing case or other fragment of the adult *Parandra*.

COMPARISON WITH ROUND-HEADED APPLE-TREE BORER

So little is published of this insect as a fruit-tree borer that its work has probably been commonly attributed to the round-headed borer, from which, however, it may be easily distinguished. The white larva, about an inch long, resembles a round-head (cerambycid) larva, but is somewhat more cylindrical, and is distinctly different in the aspect of the head and thorax. The head is small and attached at the lower anterior edge of the thorax, rather than centrally as in the common round-headed apple borer. The thorax is quite thick and its upper anterior edge is very prominent. This larva has been fully described by Osten-Sacken (Proc. Ent. Soc. Phila., Vol. I, p. 118). The adult beetle of the round-headed apple borer (*Saperda candida*) is brown with white stripes, and about an inch long, but the *Parandra* adult is chestnut red-brown in color, and of a narrow oblong form, quite parallel-sided and somewhat flattened. The round-headed borer attacks the branches more than the trunk, working under the bark and boring into the wood; the *Parandra*, while there are numerous records of its occurrence under bark, appears to be more commonly a heart-wood borer, working in the lower part of the trunk.

LIFE HISTORY

There is probably not more than one generation in a year. Our larvæ collected in December became adults July 17 to August 7. Pupæ were reported abundant in July. The adults were seen flying about actively at dusk August 5. According to Snyder,* the adults fly from July to September. Our latest date for the adult in general collections is September 25. Snyder says the eggs are probably laid from August to October. The presence in one case of numerous larvæ over half grown August 27, just subsequent to a period of pupation and emergence, and the fact that Gahan bred adults in July, 1908, from larvæ obtained December, 1906, indicates the probability of a two-year period.

SUMMARY

To summarize, fruit and small trees of all kinds, including evergreens, frequently become infested by this species at the base, especially where an injury or amputation has caused the beginnings of decay; the larvæ work upward and outward from the center, completely riddling the heart-wood, apparently entering living tissue, greatly accelerating the decay of the base to a mere shell, thus causing the death or fall of the tree; the conditions along city streets are favorable to its attack; the seriousness and extent of its injury have not been fully appreciated, and in the case of fruit trees this has been confused with that of the round-headed borer,

*Bull. 94, Pt. 1, Bur. Ent., U. S. Dept. Agr., p. 4.

from which its work may be distinguished by the fact that it is mostly in the heart-wood at the base, instead of under the bark of the branches—its larva, by its thick thorax and small low-set head—and its adult, by its chestnut red-brown color, not gray with conspicuous broad white stripes.

ANOMALA BINOTATA GYLL.

There are several species related to the common May-beetles, which in the larval form are closely similar, except for their smaller size, to the white-grubs, or May-beetle larvæ, not only in general appearance, but more or less in habits also. Among these are the various species of *Anomala*. Like the May-beetles, the *Anomala* beetles are well-known leaf-eaters; but scarcely anything is definitely known of the life histories of the species in their immature stages. The following observations on *Anomala binotata*, altho incomplete, seem worthy of publication.

In the spring of 1907 the beetles were noticed in unusual numbers near Leroy, McLean county, by Mr. E. O. G. Kelly, at that time an assistant of this office. They were first found by him March 29, among old corn roots. May 8 they began to fly and were seen on the wing all day long in oats and wheat fields. By the 10th of the month they had become quite abundant in all fields and grass lands. May 17 they were especially numerous in corn fields, some of them mating, and females were making vertical burrows in the ground for the purpose of laying their eggs. As if to attract the males, those resting on the ground sometimes spread their wings and antennæ, and soon thereafter one or more males flew against the wind to each female, and copulation followed. In one case this lasted 35 minutes, after which the female entered a nearby burrow, presumably prepared by her. Mating operations continued until May 20, and the beetles were still present May 28, when Mr. Kelly ended his work at this place.

In the fall of 1907 (September 13 to October 16) another assistant of the office, Mr. J. J. Davis, while collecting white-grubs behind the plow in various parts of central Illinois, noticed considerable numbers of small pupæ very similar to those of May-beetles except for the much smaller size; and these were shown by rearing to be *Anomala binotata*. The first adult was found in the field October 3 within a pupal cell, and the last, October 21. Pupæ collected September 13 and 17 gave adults September 18 and 28, and another lot, taken October 9, became adult October 12 to 26. In all, 18 adults and 58 pupæ were found in the fields examined. Each of the pupæ was accompanied by the cast larval skin, and all had evidently been formed during the summer or fall.

From these data it is plain that the species transforms in the ground in fall and spends the winter in the adult stage in the pupal cells. About the middle of May they are to be found emerging, flying and mating by day. The larvæ feed during midsummer, and in September the pupal stage predominates, transformation to the adult beginning early in October, and probably being completed by the end of this month.

Of the 116 fields examined by Mr. Davis, pupæ or adults were found in 30, all but one of which had been in oats, that one being in sugar corn. These 30 fields were in 10 counties of central Illinois.

The larva of *Anomala binotata* is known to me only thru the cast skins found in cells with undoubted *Anomala* pupæ. So far as structural characters are concerned, I find no evident difference by which these may be distinguished from young *Lachnosterna* larvæ of the type assigned to *L. fusca*. The sensory areas of the last antennal joint are relatively large in comparison with those of *Lachnosterna*, those of the inferior surface—on the same side as the apical tooth of the preceding segment—being quite narrowly separated. The double row of spines, hooked hairs, etc., of the ventral surface of the last abdominal segment are about as in the larva assigned to *Lachnosterna fusca*, there being about 17 or 18 spines in each of the two rows.



Fig. 6. *Anomala binotata*, abdominal spiracle of pupa.

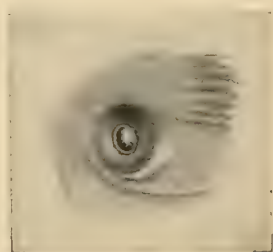


Fig. 7. *Lachnosterna implicita*, abdominal spiracle of pupa.

The pupa is easily distinguished from that of *Lachnosterna* by its smaller size, narrower head, depressed and broadly rounded tip of abdomen—this in *Lachnosterna* being quite pointed, ending in two thick fleshy spines—and by evident differences in the spiracles. In *Lachnosterna* (Fig. 7) these are small circular openings with a sharp raised rim. In *Anomala* (Fig. 6) they are large ovoid areas marked off by a fine dark line, concolorous with the surrounding surface and not raised above it; the opening a vertical slit.

The adult (Fig. 8) resembles a *Lachnosterma*, but is much smaller, only half an inch long or less, the thorax uniform blackish, the elytra each with a vaguely defined small dark spot near the center. It is decidedly hairy beneath, about as in *Lachnosterma*. The inner claw of the anterior tarsi is cleft, and differs considerably in the two sexes. In the female it is not greatly flexed, and the divisions are nearly of the same size, the lower slightly shorter. In the male the claw is strongly flexed, and the upper division is slender and short, only about half as long as the lower division, which is large and broad.



Fig. 8. *Anomala binotata*, adult female.
Length about three-eighths inch.

THE GREEN FRUIT-WORMS (*Taniocampa* and *Xylina*)

The green fruit-worms (Fig. 9, 10) are quite unlike the other common fruit pests in appearance and method of injury. They are smooth green caterpillars, an inch to an inch and a half long, very similar to common cutworms except in their color, which is a light green, with whitish or yellowish stripes, usually one on each side and one down the middle of the back. Their principal injury is done by boring or eating a large deep cavity in the young fruit, as is well shown in the illustrations. They do not spin any web nor let themselves down by a thread when disturbed, as tree caterpillars so often do, but curl up and drop like a cutworm. They not only injure the fruit of the apple, peach, plum, pear, quince and other orchard trees, but also eat the leaves of these trees; and they often feed in numbers on the leaves of several common forest and shade trees, which at times are largely defoliated by them. A

single larva may spoil several young fruits before reaching maturity; one was observed to destroy six out of eight young quinces on a tree.

Altho the green fruit-worms were introduced to Illinois fruit growers as early as 1870 by Dr. C. V. Riley, who in the *American Entomologist and Botanist* noted the identifications of specimens for three Illinois growers, they have not as yet received the attention they merit, considering that they have repeatedly damaged the apple crop of Illinois to a considerable degree.

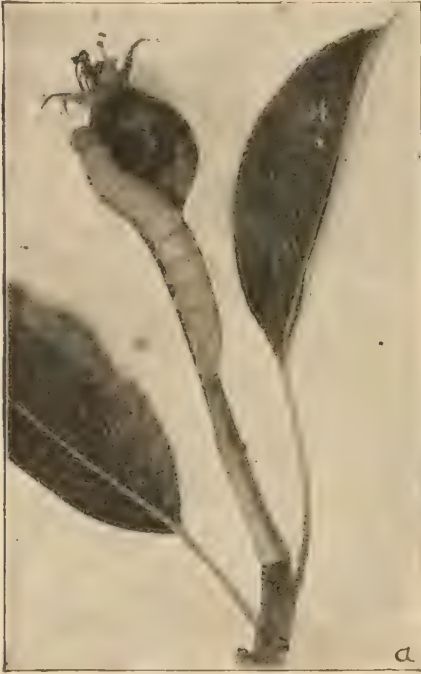


Fig. 9. Green Fruit-worm, *Taniocampa alia?* (*Xylina laticinerea* of Slingerland), larva at work. Natural size. (Cornell Experiment Station.)



Fig. 10. Green Fruit-worm, *Xylina antennata*, larva at work. Natural size. (Cornell Experiment Station.)

Mr. A. J. Dunlap, of Olney, reported to us that several varieties in his apple orchards had suffered to a great extent, the Akin being especially badly damaged; Mr. Geo. W. Emerick, of Summer, who has 100 acres in apples, stated that they were very common in his orchards, damaging his crop to the extent of about \$1,000, as many as 7 percent of the apples on some trees having been badly eaten; and Hon. H. M. Dunlap reported considerable loss, so much that he was planning additional spraying on this account. In the Clay county experimental orchards of the State Experiment Station great damage was caused the same season by these worms.

In many cases these worms have proved on breeding to belong to the genus *Xylina*. Our fullest and most satisfactory account of

the different larvæ of this genus known to cause injuries to fruits was published by Prof. M. V. Slingerland in Bulletin 123 of the Cornell Experiment Station. On the Pacific coast it has been found that species of *Teniocampa* are very destructive in orchards, one eating the fruit buds and then the leaves when they appear, another eating out cavities in the fruit after the manner of *Xylina*. The larvæ observed by us in Illinois apparently all belonged to *Teniocampa alia* and *Xylina antennata*, the former being decidedly the more abundant. *Teniocampa alia* was reared by Fitch on apple leaves about 1856, and consequently appears in Lintner's lists of apple insects.

The eastern species are widely distributed in the United States and Canada, and serious injury due to them has been reported from Canada, New York, Michigan and Missouri.



Fig. 11. Green Fruit-worm, *Teniocampa alia*(?), larva, enlarged. (Cornell Experiment Station.)

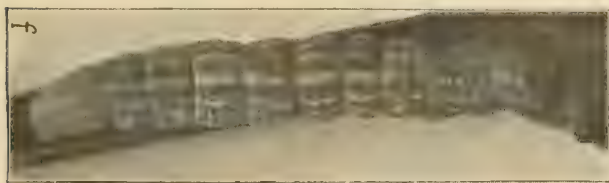


Fig. 12. Green Fruit-worm, *Xylina antennata*, larva, enlarged. (Cornell Experiment Station.)

The larvæ feed during May and early June. When mature they enter the ground, and by muscular movements form a smooth-walled cavity one to three inches below the surface. Our collections of these pupæ show that, as a rule, they are within an inch of the surface, sometimes even on the surface beneath leaves and other rubbish within the area overspread by the branches of the tree. *Xylina* spins a thin cocoon within the cavity; *Teniocampa* does not. In this cavity they change to a dark brown mummy-like chrysalis, or pupa. This change takes place in *Teniocampa* soon after the formation of

the cavity, and the pupa remains therein during the remainder of the season and over winter, emerging early in spring as a brown moth. The larvæ of *Xylina antennata*, on the other hand, remain in the cavity unchanged until late summer or early fall and then change to the pupa, emerging just about a month later as gray moths, which winter over about the bases of the trees. In any case the moths lay their eggs in spring, and there is probably only one generation of larvæ in a season.

The usual method of destroying these pests is to spray the trees with an arsenical poison. On account, however, of the small amount of the surface of the fruit eaten away by them, it has been found necessary to increase the frequency and strength of the applications to the limit of safety. The best time for spraying is when the larvæ are still quite young and just beginning to attack the fruit. This is about the first of May in the southern half of Illinois, and a week or more later northward.

Slingerland suggests jarring the trees, as for the plum-curculio, and says that this can be made more effective by encircling the trunk with some sticky band to prevent the caterpillars jarred down from climbing back into the tree. This method has already been used successfully in California against the *Taniocampa* larvæ, and may prove to be the most effective way of dealing with the fruit-worms generally. Koebele says of *Taniocampa pacifica* that if a tree be only slightly shaken, all the full-grown larvæ will drop, and that by jarring trees in the early morning the worms may be gathered and destroyed.

Feeding exposed, as they do, these caterpillars are too subject to destruction by parasites and other enemies to become injuriously numerous every year, and it is only now and then, under circumstances unusually favorable to them, that they multiply at a rate to bring them to the serious attention of the fruit grower.

TÆNIOCAMPA ALIA GUEN.

The species bred by us to *Taniocampa alia* was collected mostly in the pupal stage from the soil beneath apple trees. Our larvæ were mostly *Xylina antennata*; the few larvæ of *Taniocampa* that were taken were not recognized as different from the others until they had reached the pupal stage, and the examples preserved do not show the color pattern distinctly enough to permit a comparison with those of the species of *Xylina*. Slingerland's rearings demonstrated that there were in New York three species of *Xylina* among the green fruit-worms, *antennata*, *grotei* and *laticinerea*. In larval pattern and pupal structure (according to him) *laticinerea* differs markedly from the other two. The *Taniocampa* pupæ closely agree with those of *X. laticinerea*, as described by Slinger-

land, and were very naturally supposed to be that species until the adults were obtained.

It would be quite surprising if two species so closely related as *Xylina antennata* and *laticinerea* evidently are, should have distinctly unlike larvæ and pupæ; and it is possible that Slingerland's *laticinerea* larvæ and pupæ were really *Taniocampa*. Dr. William Barnes has very lately secured eggs from an undoubted *laticinerea* adult, and reared these again to the adult. He very kindly showed me the larvæ and sent me some of the pupæ, and they seem exactly like those of *antennata*.

Out of 6 larvæ and pupæ taken from earth under apple trees at Carbondale, 5 were recognized as *antennata*, and proven to be such by rearing; but elsewhere the other type—bred by Slingerland to *laticinerea* and by us to *Taniocampa alia*—greatly predominated in our collections. Of 31 pupæ from Flora, Centralia and Olney, 28 were of this type, the other three being *antennata*.

Larvæ of *alia* were collected May 11, 12, 15 and 22. The date of maturing and entering the ground for pupation is recorded as May 27 in two different years, and May 24; that of pupation, as May 24 (7), 30, and June 1, 2 and 7. The interval between entering the ground and pupation was 4 to 6 days. No imagos have ever been bred or collected by us in fall; the pupæ remained as such during the remainder of the season and the winter following, emerging in spring. The first adult to appear was probably hastened by conditions of rearing; it emerged March 21, and the others appeared April 2 and May 14. Adults have been taken by us at lights and "sugar" April 1, 9, 11, 12, 13, 14, 15 and 29 and May 8.

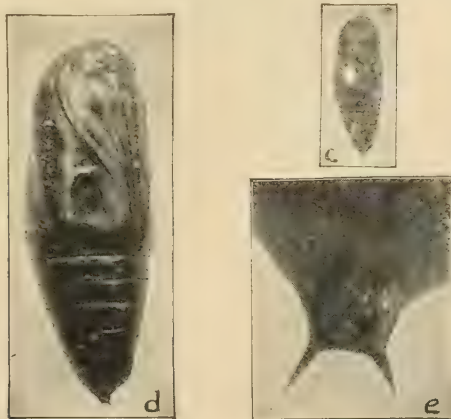


Fig. 13. Green Fruit-worm, *Taniocampa alia*. pupa: c, natural size; d, enlarged; e, tip of abdomen. (Cornell Experiment Station.)

The pupa (Fig. 13) is of the usual form, dark chestnut-brown, about 15 mm. long, the dorsum terminating at the posterior end in a

small knob bearing a pair of stout diverging spines. The dorsum is moderately rugose and sparsely punctate on the thorax and the first three abdominal segments; the remaining segments are smooth and more shiny. Segments 4—7 have at their anterior margin, above, a row of large punctures, becoming blackish and very large and deep toward the median line. Segment 6 is sparsely punctate laterally; the anterior half of segment 7 laterally and segment 9 laterally and dorsally are moderately punctate; segment 7 ventrally and on the anterior half and segment 8 thruout are finely and rather densely punctulate; and 5 and 6 are grooved on the median ventral line, flattened below and angulated each side of this at the location of the false feet.

XYLINA ANTENNATA WALK.

Our larvæ of this species taken on apple leaves were collected May 12 and 27, except one which was found as late as July 7. One larva matured and entered the earth May 22, and another July 14. Unlike the preceding species, pupation does not usually take place in a few days after the larva enters the ground, but seems to occur irregularly thruout a considerable period, and is usually delayed until fall. Of five individuals found July 25 in cells in the ground under apple trees, four were still in the larval stage, and one was a pupa. In our breeding-cages pupation took place August 19, 20 and 31, and September 3 and 10. The pupal period averaged about 32 days. The adults emerged August 17 (from a pupa found August 1), September 16 and 19, and October 7 and 8. Another series of larvæ, taken in a different year, gave 15 adults, emerging September 16, 28, 29 and 30, October 9, 10, 14, 15 and 16; two appeared October 9, and four on the 10th. None of this lot hibernated as pupæ. Slingerland's dates of emergence of this species ranged from September 13 to October 6. The adults winter over, and may be captured in winter and early spring; very likely some may not emerge till spring. Two of our pupæ which did not transform at all were apparently alive and healthy in the early part of the winter, and probably adults would have emerged in spring if under normal conditions. Our dates of capture of adults are September 29, October 31, December 14 and 18 (in fallen leaves), February 24, March 17, 21, 22, and April 1. Slingerland lists dates from August 4 to April 20, with two records for May without exact date.

The pupa (Fig. 14) differs from that of *Teniocampa alia* in the following minor details. It is impunctate and shining, and without any ventral grooves or angulations on segments 5 and 6 of the abdomen, tho the anterior margin of each abdominal segment bears a narrow band of rather dense, fine punctures; the terminal knob is longitudinally wrinkled above, and bears two large spinous filaments

set close together and parallel, their tips curled outwards, also four smaller and lighter-colored ones about half as long, similarly straight, and curled at tip.

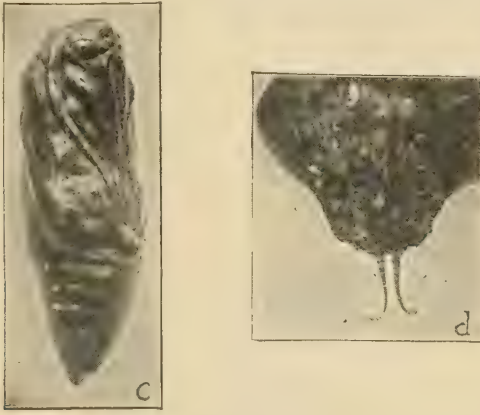


Fig. 14. Green Fruit-worm, *Xylina antennata*, pupa: c, enlarged (natural size about as in Fig. 13, c); d, tip of abdomen. (Cornell Experiment Station.)



Fig. 15. Green Fruit-worm, *Xylina antennata*, adult moth at rest, natural size. (Cornell Experiment Station.)



Fig. 16. Green Fruit-worm, *Xylina antennata*, adult. (Cornell Experiment Station.)



Fig. 17. Green Fruit-worm, *Xylina laticinerea*, adult. (Cornell Experiment Station.)

The known differences between the green fruit-worm species may be tabulated as follows.

Larvæ:

Yellowish green; lateral stripe broad, including the spiracles; piliform spots white, distinct; a few white dots in the ground color.

Upper edge of lateral stripe irregularly indented and interrupted; subdorsal stripe narrow, but continuous.

(Fig. 12.) *X. antennata*

Upper edge of lateral stripe even and sharply defined; subdorsal stripe discontinuous, represented by 3 or 4 spots on each segment *X. grotei*

Light apple-green, sometimes with a bluish cast, all stripes narrow; lateral stripe running above the spiracles except at each end; ground color finely mottled with cream-colored dots. (*Tæniocampa alia?*) (Fig. 11) *X. laticinerea* (Slingerland)

Pupæ (Slingerland):

With cocoon; terminal knob bearing two large and four small parallel spinous filaments, curled up at tips (Fig. 14) *X. antennata* and *grotei*

Without cocoon; terminal knob bearing a pair of stout divergent spines apically, one on each side (Fig. 13). (*Tæniocampa alia?*) *X. laticinerea*

Pupæ (this office):

With cocoon; terminal knob as described by Slingerland for *antennata*; each abdominal segment with narrow band of fine punctuation at anterior margin, otherwise impunctate. (Fig. 14.) *X. antennata*

Without cocoon; terminal knob as in Slingerland's *laticinerea*; abdominal segments 4—7 above with a single row of coarse punctures, median ones very large and deep; all of segment 8 and the anterior half ventrally of 7 finely and rather densely punctulate. (Fig. 13.) *Tæniocampa alia*

Life History:

Mostly passing the summer as larvæ; pupating and emerging in fall and hibernating as adults. *X. antennata* and *grotei*

Passing the summer, and mostly or entirely hibernating, as pupæ, and emerging in spring. *Xylina laticinerea* (?), *Tæniocampa alia*

THE APPLE FLEA-WEEVIL

(*Orchestes canus* Horn)

The apple flea-weevil is a small, dull blackish beetle (Fig. 18) nearly one-eighth of an inch long, resembling the common flea-beetles in general appearance; and, altho a true weevil or snout-beetle, it has the power of leaping like the flea-beetles. The larvæ (Fig. 19) make winding burrows (mines) in apple leaves; the pupæ (Fig. 20) are formed within the leaf; and the adults feed on the leaves, making numerous shallow pits which later become small holes.



Fig. 18. Apple Flea-weevil, *Orchestes canus*, adult. Length about one-eighth inch.



Fig. 19. Apple Flea-weevil, *Orchestes canus*, larva. Length about one-eighth inch.

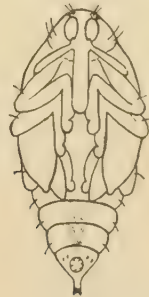


Fig. 20. Apple Flea-weevil, *Orchestes canus*, pupa, seen from below. Length about one-eighth inch.

The species was first found injurious to the apple by the writer and Mr. E. S. G. Titus in 1901 at various points in the apple region of the southern third of Illinois, when, as assistants of the Entomologist's office, we were making a study of apple insects in that part of the state. It was again found the following season by Mr. Titus, and by Mr. E. P. Taylor in 1905, thruout the same region, and in western Illinois by the writer in 1906. It was at first supposed to be *Orchestes pallicornis* Say, and the first published account of its injuries appeared under that name in the Transactions of the Illinois State Horticultural Society for 1901.

APPEARANCE AND AMOUNT OF INJURY

The completed mine (Fig. 21) is conspicuous as a rather bright red blotch about one-fourth of an inch in diameter, somewhere along the margin of the leaf near its outer end; and the pupal chamber is indicated by a dark brown gall-like swelling near the



Fig. 21. Apple Flea-weevil, *Orchestes canus*, mine of larva in apple leaf.

center of this blotch. Often the small passage mined by the newly hatched larva is seen leading from the inner part of the leaf to the mined area. Mr. Taylor noticed that there was always a small swelling on one of the principal veins near the point where the larva first began to mine the leaf, and he assumed that this indi-

cated the point where the female beetle inserted the egg which produced the larva. This swelling was always on the lower side of the leaf, and caused the vein to angle slightly upwards at this point, noticeably tilting up the part of the leaf beyond the injury.

The beetles, in feeding, eat out the soft tissue between the smaller veinlets, but leave the surface layer of the opposite side, thus making a minute shallow pit one-half to one millimeter in diameter (one-fiftieth to one-twenty-fifth of an inch) closed at the bottom by a more or less transparent membrane, which is the dry epidermis of the opposite side. These pits are usually in groups of two or more, separated only by the veinlets and a little leaf-tissue. The beetles usually feed on the lower surface, but sometimes on the upper surface also, especially on woolly-leaved varieties. As an effect of these injuries the leaves become ragged near the tip and riddled with small holes.

Injuries by this species are not uncommon thruout southern Illinois, and in some places were abundant enough to be of economic importance. In one orchard Mr. Taylor counted fifty-eight mined leaves on a single branch three feet long, and collected several hundred leaves bearing the characteristic pupal chamber. In another orchard, visited by Mr. Titus and the writer, the beetles were very abundant on the leaves, which were thickly and conspicuously peppered with small pits.

LIFE HISTORY AND HABITS

The eggs are apparently inserted in the outer part of the leaf in one of the principal veins. The young larva begins to mine the leaf near by, invariably starting toward the outer margin. Upon nearing this it enlarges the mine in all directions, obliterating all or a large part of its original passageway. The mine remains quite flat until the larva is about full-grown, when it becomes hemispherical above and slightly swollen below; and in the chamber thus formed the larva pupates. The adults emerge from the chamber by breaking it open at the center on either the upper or the lower side. When touched they leap away with a quick snap, like the flea-beetles; when the leaf on which they are feeding is disturbed, they feign death and drop to the ground.

The earliest date for this insect is April 27, for the completed leaf mines at Carbondale; the earliest record for the adult is in a note by Taylor to the effect that he has seen the beetles abroad for several days before May 15. The adults have emerged in largest numbers during the last week in May from many mines collected in different years, and the latest date of emergence was June 4. The beetles were seen by us on apple leaves thru the month of June,

but not thereafter. The beetles winter over and lay their eggs soon after the leaves open, adults of the new generation appearing from the first part of May to the first part of June, and continuing at least thru the latter month. The remainder of the life history is unknown.

DISTRIBUTION OF SPECIES

The species was first recognized and described by Dr. G. H. Horn in 1878, from specimens of the adult from Michigan and Colorado.

In Illinois we have seen it or its characteristic injuries at about thirty different towns: in Pulaski, Union, Jackson and Williamson counties in extreme southern Illinois; in the prairie fruit region of Washington, Jefferson, Marion, Clay, Wayne, Edwards and Richland counties; in Jersey, Calhoun and Pike counties in the western part of the state; and in Coles and Christian counties in south-central Illinois. It is represented in our collections by several specimens labeled "N. Ill.", and by one from Normal, McLean county; and it will probably be found to infest apple trees thruout the state.

NATURAL CHECKS AND REMEDIES

The species is probably usually kept under control by a chalcid parasite (a species of *Eulophus*, according to Mr. A. A. Girault), which has been reared by us three times. In mines collected May 8 and 22 pupæ were found May 21 and 25, and adults of this species were secured May 26 and 27. From material collected May 15 a considerable number of these parasites were bred May 30 and June 3.

The injuries caused by the apple flea-weevil do not as yet appear to be serious enough to make insecticide applications necessary. If they were, an arsenical spray applied near the end of May would no doubt kill the beetles, since they are at that time feeding on the leaves. Especial care would be necessary to reach the lower sides of the leaves with the spray, since they feed mostly on that side, and do not eat thru the leaf.

THE STRAWBERRY LEAF-ROLLER

(*Ancylis comptana* Fröl.)

This troublesome enemy of the strawberry grower is an active, small, slender, greenish larva (Fig. 22, *a*, *b*, *d*) about half an inch long when full-grown, and having seven pairs of legs. It folds the strawberry leaf, living within the fold, where it spins a silken web and feeds on the leaf tissue. The foliage is often thus seri-

ously injured, and the quality of the fruit correspondingly affected. The brown pupa is formed within the fold, and in time changes to a small miller (Fig. 22, c) about two-fifths of an inch across the spread wings, the front wings red-brown, marked with white lines and spots, the hind wings dark gray.

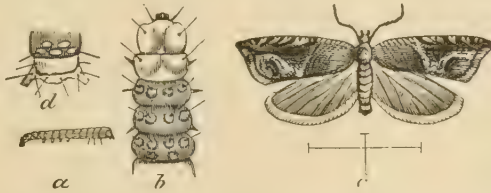


Fig. 22. Strawberry Leaf-roller, *Ancyliis complana*: a, larva, natural size; b, head and fore part of larva, seen from above; c, adult moth; d, posterior end of larva seen from above.

As we lack exact information concerning the number of generations and other details of the life history of this insect, experiments and observations on this subject were made in the fall of 1905 and during 1906 by Mr. J. J. Davis, an assistant of this office. Table I tabulates the life history data obtained by him, starting with the first brood in spring and tracing the appearance and period, in days, of the successive stages of the four broods thruout the season, as they appeared in the different years, using a separate line for each brood of each year.

TABLE I

Broods	Eggs first noticed	Egg period	Larvæ began hatching	Larval period	Pupation occurred	Pupal period	Adults emerged
IV, '05			(Larvæ collected Aug. 1)		Aug. 3-17 (26 examples) Mean, Aug. 7	8 days. (2 exam.)	Aug. 12-16 (11 examples) Mean, Aug. 14
I, '05 — '06	Aug. 19 (from adults emerging Aug. 16)	6 days	Aug. 25 (Larvæ collected Aug. 31)	winter (died)	April 21-25	(?)	May 2
II, '06	May 2-4	9-10 days	May 13	21-29 days	June 3-22 (Pupæ collected June 16.)	9.6 da. 10+ days	Jun. 11?-Jul. 1 June 18-26
III, '06	June 23	6 days	June 29	20-24 days	July 19-23	6-10 da. Mean, 7.5 da.	July 25-31
IV, '06	July 28	5-6 days	Aug. 2-3	16-20 days	Aug. 18-22 (13 examples) Mean, Aug. 20	6-8 da. Mean, 6.7 da.	Aug. 24-29
I, '06 (In fall)	Aug. 31	5 days	Sept. 4	winter			

It will be noticed that Davis collected in the field larvæ of the last (fourth) brood August 1, 1905. These pupated August 3-17 and the adults began to emerge August 12. August 16, two emerged, a total of 11 in all, and these two and the remaining pupæ were transferred to another breeding cage. Eggs were noticed in this cage August 19, and larvæ hatched from them August 25, but subsequently died. Fresh larvæ were then collected in the

field August 31, and these wintered over in the cages in this stage. Examinations of field conditions December 13 showed the species to be abundantly present in the larval stage only. The hibernating larvæ in the cages pupated between the 21st and 25th of the following April, and adults emerged May 2. This generation may be regarded as the first of the year. Eggs from these adults, beginning the second generation, were seen May 2-4, and began to hatch May 13. Pupation occurred June 3-11, and adults appeared June 11 (?) and 19. In another lot of larvæ of this brood, pupation occurred June 17-22, and the adult stage was reached June 23-July 1. No eggs of the third generation were secured from these adults, but additional pupæ of the second generation from the field June 16 gave adults June 18-26, from which eggs of the third generation were obtained beginning June 23. These began to hatch June 29. The larvæ pupated July 19-23 and these pupæ became adults July 25-31. Eggs of the fourth generation from these adults were first noted July 28, and these hatched August 2 and 3. Thirteen larvæ pupated August 18-22, and gave adults August 24-29. This fourth generation may properly be correlated with the larvæ of August 1, the pupæ of August 3-17, and the adults of August 12 and later, of the preceding season. From the adults of August 24-29 eggs were obtained August 31, from which larvæ began to hatch September 4, which entered the winter without transformation, belonging therefore to the first generation of the following season.

The species produces consequently four generations in central Illinois, not two or three as has been previously supposed. Table II shows graphically the distribution of generations and stages thruout the season.

TABLE II

	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
Egg		II	III	IV	I		
Larva	I	II		III	IV		I
Pupa		I	II	III	IV		
Imago		I	II	III	IV		

The egg period in the second generation, in early May was 9 or 10 days; during the remainder of the season it was 5 or 6 days. The larval period, except that of the hibernating generation, varied from 29 days in May to 16 in July. The pupal period of the third and fourth generations varied from 6 to 10 days; the maximum for the second generation was at least 10 days and probably more.

The eggs are oval and flattened, varying in size from $.4 \times .5$ mm. to $.6 \times .7$ mm. They are placed singly, very closely attached and

inconspicuous, on the lower surface of the leaves, usually along the principal veins. Young leaves, which have many fine hairs on the under surface, are freest from them.

The newly hatched larva is not more than 1.25 mm. long. It feeds at first exposed, mostly on the under surface, gnawing the epidermis as do most young caterpillars, and not cutting thru the leaf. A few days later it begins to make a web and roll up the leaf, eating holes entirely thru it. The hibernating larvæ were first seen to feed April 21, only a few days before pupation.

The pupa is invariably formed within the rolled leaf.

The adults copulate soon after emergence. Copulation has been observed on three different occasions, in all cases between 8:30 and 9:30 p. m. Egg-laying begins within two or three days after emergence.

The two remedies most frequently recommended are burning over the fields after harvest, and spraying the plants with some arsenical poison in spring when the larvæ are hatching, and before they have rolled the leaves to any extent. The latter period comes so soon before the ripening of the first fruit that some other plan is very desirable. It is a common practice to consider infested fields as worthless and to destroy them by plowing after harvest. Mr. Fred Hubbard, an enterprising strawberry grower of Urbana, conceived the idea of spraying his fields after harvest, and representatives of this office have investigated the results. The spray used was arsenate of lead, 1¾ pounds of lead acetate and 11 ounces of arsenate of soda to 100 gallons of water. The field was sprayed once a week from the close of the harvest until frost. Four rows in the middle of the field were left as checks. A thoro examination of the field after the close of the spraying gave the most positive evidence of its good effect. The unsprayed rows could readily be picked out. The sprayed plants had more foliage, and it was all of a healthy rich green color, while the foliage of the unsprayed rows was discolored and less abundant. The larvæ were very common on the unsprayed rows and entirely absent from the sprayed rows.

The effect of this treatment upon the crops of the succeeding season was marred by two facts: first, the reinfestation of the sprayed rows from the adjoining unsprayed ones left as checks; second, the general reduction of numbers among the leaf-rollers due to natural causes. Strawberry fields everywhere, regardless of treatment, were comparatively free from them that season and a good crop of fruit was secured. If the entire field had been sprayed there is every reason to suppose that even under the most favorable conditions for leaf-rollers the field would not have again become infested the following spring, and that no damage to the crop from this cause would have occurred.

THE STRAWBERRY CROWN-GIRDLER

(Otiorynchus ovatus Linn.)

This insect is a black snout-beetle about one-fifth of an inch long, which feeds on a great variety of plants, and occasionally makes itself a nuisance to housekeepers by swarming into houses in the fall. Its larva is a small whitish grub which girdles the crown of the strawberry and feeds on the roots of strawberry, white clover, grasses and other plants.

Serious injury was done by this insect, in 1905, to the strawberry beds of Mr. Geo. Wirt, at Alpha, Ill. The excellent observations of its peculiar habits reported at about the same time by the experiment stations of Maine and Montana, together with our own observations in connection with the Alpha outbreak, make possible a fairly satisfactory account of this insect and of the best methods of destroying it. It is northern in its distribution, occurring mostly in the northern half of the United States and in Canada, altho there is a record of its occurrence as far south as Santa Fe, N. M.

LITERATURE

It was first reported as a strawberry insect by C. M. Weed in 1884 (14th Mich. Hort. Soc. Rep., p. 84). In 1895, Dr. Lintner, State Entomologist of New York, discussed it in his 10th report, p. 416, especially because of the annoyance caused by its peculiar habit of infesting houses. In 1899 its serious injuries in Minnesota were noted by Mr. Lugger in his 5th report as State Entomologist. In December, 1904, Mr. R. A. Cooley, State Entomologist of Montana, reported careful observations in connection with destructive outbreaks at two localities in his state, in his second report (Bull. 55 of the Montana Exper. Sta., p. 130). In Maine, Miss Edith M. Patch, Entomologist of the Experiment Station there, has published valuable observations on the life history of the species in Bulletin 123, and it was briefly treated as a corn insect in the 23d report of the Illinois State Entomologist.

STAGES

In its larval form the strawberry crown-girdler is a short, thick-bodied, footless, small white grub about three-eighths of an inch long, with a yellowish head. It is very similar in appearance to the larva of the plum-curculio. It devours the roots and rootlets of the strawberry, and gnaws the crown of the plant, mostly on the outside, often completely girdling it, whence its name of crown-girdler. There are several other small larvæ which feed on the strawberry roots and crown, whose life histories and distinctive

characters are treated in the 13th report of this office, pp. 141, 142 and 143. These are the strawberry crown-miner (*Anarsia lineatella*)—easily recognized as a slender, reddish caterpillar with numerous short legs—and several beetle larvæ similar in form to the crown-girdler, but somewhat smaller when adult. One of the most important of these is the true strawberry crown-borer (*Tyloderma fragariæ*), also a footless grub, which mines the interior of the crown, within which it changes to the pupa. The crown-girdler, on the other hand, feeds mostly externally on crown and roots, and pupates in the earth near by. Very similar in habits to the crown-girdler are the three species of strawberry root-worms (*Typophorus canellus*, *Colaspis brunnea*, and *Scelodonta nebulosus*), all larvæ of the plant-beetle family *Chrysomelidæ*; but these all have a pair of small but distinct legs on each of the three segments just back of the head.

The mature larva forms a cell in the earth near by, where it changes to a whitish inactive pupa, which in about ten days becomes an adult.



Fig. 23. Strawberry Crown-girdler, *Otiorynchus ovatus*, adult. Length about one-fifth inch.

The adult (Fig. 23) is a black snout-beetle, or weevil, about a fifth of an inch long, with a short, thick snout or beak. The strawberry crown-borer is also a snout-beetle, but has a slender beak. The crown-girdler adult is easily recognized, also, by its curiously globular thorax and egg-shaped hind-body, in conjunction with its black color and its wrinkled, uneven surface, all well shown in the figure. These beetles hide by day about the summit of the crown, forming burrows about the bases of the leaf-stems for convenient access, and feed by night on the leaves, eating small, irregular

patches from them, and gnawing the leaf-stems and even to some extent the crown and roots.

FOOD PLANTS

The species does not by any means confine its attacks to the strawberry plant, but is in fact a very general feeder. The larvæ are also known to breed freely in the roots of wild strawberry, white clover, balsam-root (*Balsamorhiza sagittata*, a western plant), *Potentilla glandulosa* (another western species), and on timothy, June grass, *Poa flava* (*P. scrotina*), and other grasses. We have in Illinois two species of *Potentilla*, which are common weeds closely related to the strawberry, and probably these and numerous others also serve as food plants for the larvæ. The adult beetle is a still more general feeder, eating the leaves of the plants whose roots are eaten by it in the larva stage. It also feeds on the corn plant, and on several others. Miss Patch gives a list of 54 species upon which the beetles fed more or less readily when confined for a period not exceeding three days with the leaves or the blossoms. We once found the beetles at the roots of pumpkin.

LIFE HISTORY

The species undoubtedly spends the winter as a beetle, and, according to Cooley, in the larval stage also. We have found what were probably hibernating beetles twice in early April, and also in October. At the time of the Alpha outbreak, May 26, the larvæ, which were almost certainly from eggs laid by hibernating beetles, had mostly completed their growth and changed to pupæ, and a few had become adult. From a number of pupæ placed in breeding cages, adults emerged at frequent intervals thruout June. These adults were confined with strawberry plants, and from them a number of eggs were secured in the latter part of June. A few weeks later the eggs had well-developed larvæ within them, and some apparently hatched, but if so, they failed to develop on the roots of the plants, as none could be found, altho a most careful search for them was made.

Cooley had somewhat better results. He collected adults late in May, presumably of the hibernating generation, from which he was very successful in securing the eggs in June, most of which were scattered thru the soil and in the burrows made by the adults, and late in June, after a period of about 20 days from the laying of the first eggs, a few young larvæ were discovered. He did not succeed in rearing them, however. These probably represented the first larval generation of the year, the dates being a little later than those for this generation in central Illinois, but not

so late as the eggs in our breeding cages, which seem to belong to a second generation. Adult beetles believed to be of this second generation were found abundantly by us August 21, in the grass in the apple orchard of H. M. Dunlap, at Savoy, not far from Urbana, but not near any strawberry bed. Some of these beetles were put in a cage with the grass (*Agrotis major*) in which they were found. They lived until late in September, finally dying, probably as the result of artificial conditions, but no signs of feeding or oviposition could be discovered. Cooley remarks that the beetles come together, as if for hibernation, as early as August, and that the periods of the different stages overlap, so that it is very difficult to determine the number of generations, all stages being found together at the same time, the indications being, however, that there is but one generation a year in his state. In Illinois, as shown by our observations, there are apparently two generations of larvæ, one in May and one in July, the first becoming adult in June and the second in August, the latter hibernating until the following April.

OTHER BIOLOGICAL DATA

A peculiar feature of the occurrence of this species in unusual numbers is its limitation to very small areas, and the lack of any decided tendency to scatter widely and infest large areas when its numbers become excessive. This is probably due to the fact that the adults are wingless, their wing-covers being solidly grown together, so that they can not fly; hence their only means of dispersal is by crawling, except when they are introduced into a new district on strawberry plants from an infested field. Mr. Cooley has suggested that they may be limited by certain soil conditions; but this seems unlikely. That they do migrate to some extent in search of suitable winter quarters is shown by their entering houses.

In the Alpha strawberry fields, the principal infested plot had shown injury over two small areas the preceding spring, which was the third spring after planting. The more severe injury was still limited to these areas, but there was now evidence of injury in other parts of this plot, and also in the edge of another, adjacent. Two plots, separated from these only by a lane, showed no sign of the insect or its injury.

The infested leaves were reddened and small, and the crowns were so weakened by injury and decay that the plants and a layer of straw on the ground could readily be rolled up together like a carpet. Larvæ and pupæ were very numerous, mostly about two inches below the surface; the adults were less numerous and were well hidden in the straw and among the lower leaves. In Maine, an area of three square feet in an infested patch was carefully examined, and more than 200 individuals, nearly grown larvæ, pupæ,

and adults, were found. More than half of the plants were killed. At one infested spot in Montana the species has prevented the profitable growing of strawberries for eight or ten years.

Like the box-elder bug, these beetles have perhaps attracted more attention by entering houses when in search of winter quarters than by their injuries to the strawberry plant. In late summer they wander about in large numbers in the neighborhood of infested strawberry plots, and if a house happens to be near by they often come into it in astonishing numbers. In one case more than four hundred were killed in one evening in a single room, and the beetles traveled all over the house, crawling up the walls to the ceiling only to drop to the floor, and making this journey over and over again. They are not attracted by lights, as some have supposed.

REMEDIAL MEASURES

From experiments made by us, and also at the Montana station, it appears that the beetles avoid leaves which have been sprayed with arsenical poisons, and feed then upon other parts of the plant.

On the other hand, notwithstanding the general feeding habits of both larva and adult, there is evidence that a satisfactory rotation can be arranged that will completely clear an infested plot. Miss Patch examined one infested area in which there were no cultivated strawberry plants. She found the larvæ infesting roots of wild strawberry, grasses, and white clover, but an examination of large potato fields close at hand revealed no signs of the insect. Mr. Cooley also suggests the potato as a possible crop for this purpose. He suggests that infestation of strawberry plots probably does not originate among the strawberries, but is due to the planting of ground already infested. In this connection the history of the Alpha plot is of interest. It was used for a strawberry crop, then set with young fruit trees for two or three years, then used again for strawberries, the injury first being noted in the third season of this second planting to strawberries. Cooley mentions an instance in Montana where infested strawberry land was planted to other crops for a few years, and when subsequently replanted with strawberries was not re-infested.

THE BLACKBERRY LEAF-ROLLER

(*Exartema permundanum* Clem.)

The larvæ of this leaf-roller were found at Decatur, Ill., June 25, 1905, feeding in small numbers on blackberry, raspberry and strawberry plants.

They were reared to the adult (Fig. 24) in the insectary, and the moths deposited eggs, singly, on the glass of the breeding cage.

The eggs are yellow at first, and are oval in outline, measuring about $\frac{1}{2} \times \frac{3}{4}$ of a millimeter. In about five days the young larvæ hatched, and at once formed a nest by drawing several of the young leaves together. At first they ate only the epidermis in irregular patches, but when they grew older they ate thru the leaf.

From the original larvæ, collected June 25, adults were obtained July 5-17. The first eggs from these adults were laid July 12, and hatched on the 17th. The larvæ grew slowly, and September 7, when only about four millimeters long, they began to prepare for hibernation. A part of the outer edge of the leaf, half an inch or less in length, was folded over upon the upper surface nearly to the midrib, each larva thus forming a shelter for the winter.



Fig. 24. Blackberry Leaf-roller, *Exartema perminuatum*, adult moth, with outline showing natural size. (Saunders.)

One larva passed the winter successfully, and came out about the first of April, but was not fed until April 21, when a strawberry plant was put into the cage, and was at once fed upon. The larva pupated May 28, and the adult emerged early in June.

The larvæ taken at Decatur June 25 apparently came from eggs laid by moths from hibernating larvæ, and in that case the species apparently normally produces two generations. Two exceptions to the above life history which appeared in the cages indicate that there is some variation in this respect. One of the original larvæ did not pupate and become adult with the others in July, but remained in the larval stage and folded the leaf as if for hibernation; it died, however, before the arrival of winter. On the other hand, one of the next generation of larvæ did not winter over with its fellows, but pupated, yielding a moth the same season, August 15.

BLACK GNATS IN CUCUMBER HOUSES

(*Sciara* sp.)

From time to time complaints have come to us from the cucumber forcing-houses of northwestern Illinois, particularly from Dixon and Morrison, county seats of the two adjoining counties of Lee and Whiteside, respectively, of a serious wilting of cucumber

plants, associated with the appearance of swarms of small, blackish, gnat-like flies. An assistant of the office, Mr. E. C. Green, was sent to the scene of the injury to investigate and experiment, and this account is mainly a summary of the results secured by him then.

The flies belong to the family *Mycetophilidæ*, or fungus flies, and to the genus *Sciara*. The larvæ of this large family seem to feed primarily on decaying vegetable matter, and records of their directly attacking healthy living plant tissues are rare. However, as is often the case with insects of this habit, their presence in decayed parts of plants, or even in close association with plants, seems in some way to promote decay. The larvæ of this genus are small, slender, glassy white, footless maggots, a third of an inch long or less, and usually with black heads. A species common in wet corn fields following sod, which sometimes eats the softened seed corn, especially in cold, wet springs, is treated in the eighteenth report of this office, where it is called the black-headed grass-maggot. The frequent occurrence of similar larvæ in rich soil, especially in flower-pots and greenhouses, is also mentioned in that article.

Mr. Green found numerous cases of the excessive abundance of such larvæ in the soil of forcing-house benches, and swarms of the flies, often in such numbers as to blacken the woodwork. The close association of these maggots with wilted and ruined beds of plants, and the invariable presence of numerous larvæ about the bases and roots of wilting plants, strongly indicate that these larvæ were the cause of the injury.

When the cucumber plant wilts in the presence of these *Sciara* larvæ, the lower leaves are affected first. These droop and finally hang down, gradually dying from the edges inward until the whole leaf is dried and shriveled. The rootlets and smaller roots of wilted plants are dark-colored and dead. The maggots are usually excessively numerous in the soil about such plants, often especially so about the main stalk. In no case were the maggots found attacking a firm, healthy stalk or root, but at the least appearance of decay they attacked it in great numbers, gnawing the surface and tunneling thru it in all directions. If the larvæ are full-grown and rapidly pupating at the time, and the flies are also beginning to appear in large numbers, the plant usually survives the injury without assistance, showing signs of recovery in a day or two. An examination of a plant at this stage shows numberless little, white, new rootlets starting from the main stalk and larger roots. If, however, the maggots remain and continue their work several days after the first wilting of the plants, these do not recover.

In the fields these maggots have been noticed mostly in May and June, but indoors and in hothouses they may occur at any time of the year, and the life cycle is probably rather short, so that there

may be quite a number of generations in the course of a year. Some freshly-laid eggs of this species, gathered January 13 and placed under glass, hatched about eighteen days later.

Mr. Green made experiments to determine the food preferences of the larvæ. A cucumber plant was potted in clean sand, and 100 of the maggots were placed about its base. These affected the plant, the stem being evidently eaten by them. The same experiment was made with the addition, at one side of the pot, of a cubic inch of decayed horse manure, such as is mixed with earth in growing cucumbers. The larvæ were subsequently found collected about the piece of manure and the plant remained uninjured. Next a plant was potted in a mixture of manure with earth from the forcing beds infested by maggots. The plant was not injured. These experiments, although on too small a scale to be decisive, confirm the supposition that the maggots feed preferably on decaying manure, injury to the living plants resulting only in case the larvæ are excessively abundant.

A very careful and extended study was made by Mr. Green of the history of infested beds at Dixon and Morrison, with especial reference to the source and treatment of the manure mixed with the earth used in making up cucumber beds. Severe infestation invariably followed the use of fresh horse manure in fall. For example, in one case beds were started in the fall with soil from an old pasture mixed with fresh horse manure. When the plants were about five inches high they suddenly wilted and all died, and the flies soon came out in such numbers as to cloud the glass in the houses. The whole place was thoroly cleaned and whitewashed, and a new start was made with more manure from the same source and earth from a nearby cultivated field. Serious injury again followed, and the flies became as thick as before.

In another case manure was collected from livery barns, and in late summer and fall some fresh manure was added, also soil from river alluvium and old land, and the beds were started with the mixture. Four weeks later the plants began to wilt and about three-fourths of them died. In a similar case as to material used the soil was steamed three hours, but without apparent effect, as the flies became very thick and about 50 percent of the plants were lost.

When the manure used was gathered in winter or early summer and well rotted before using, little or no injury followed.

In another class of instances, where the manure used was composted with lime, no injury resulted unless, as was frequently the case, fresh manure was added to make up a deficiency, when the injury varied with the amount of fresh manure used. In one case the infestation was slight at first, but reached serious proportions by the next spring. In another case the additional fresh manure

was all used on a certain bed, the other beds being prepared with composted manure. The bed with fresh manure was a total loss; the others showed no injury. The ruined bed was simply replanted, and there was no further injury. In another case the manure, altho obtained in fall, heated greatly in rotting, and no serious injury followed its use.

One fact observed by Mr. Green may be of value in combating these pests. He found them much less numerous and troublesome in the drier houses than in those where water was freely used and moist conditions prevailed.

It was thought that perhaps some repellent might be introduced about the bases of the plants to drive away the maggots, and Nickoteen, a proprietary decoction of tobacco stems, was tried for this purpose. It was found that $\frac{1}{2}$ of 1 percent of Nickoteen in water repelled the larvæ without injuring the plants. A 6 percent application of Nickoteen caused a temporary wilting of the plants and higher percentages killed them.

One curious result of the Nickoteen application should be especially noted. In an infested forcing house 135 feet long, containing three benches, the east bench was treated with 1 percent Nickoteen, a gallon to each rod of bench, the west bench with 2 percent, a gallon to each yard, and the middle bench was left as a check. The treatment of both side benches had the effect of precipitating the transformation of the larvæ. These pupated prematurely, without waiting for complete development, and soon clouds of flies darkened the interior of the houses. These flies seemed to be weakened by their hasty transformation and died in unusual numbers. Evidently, in cases of sudden wilting, when speedy relief might mean the saving of a large part of the crop, such a treatment might be of great value, and further experimentation with this and similar insecticides is especially to be desired.

To summarize the results of the investigation, it may be said that all cases of severe injury to cucumbers in the forcing houses followed the use of fresh horse manure in fall; that if the manure had been gathered earlier in the season and well rotted or composted with lime, or gathered in winter, little or no damage appeared; that the injury was much worse in the moister forcing houses than in the drier ones; that Nickoteen in water, in strengths of $\frac{1}{2}$ to about 6 percent, will force the insects prematurely thru their transformations to the adult stage, weakening them so that many die; and that if the injury be of short duration the plants are likely to recover, but that if it continues more than a few days the plants will die and the crop may be a total loss.

ON THE MORE IMPORTANT INSECTS OF THE TRUCK-FARM AND VEGETABLE GARDEN

BY J. J. DAVIS, ASSISTANT ENTOMOLOGIST FOR NORTHERN ILLINOIS

Vegetable gardening is now one of the most important of the various agricultural interests of Illinois. According to the census of 1900 there were 256,213 acres in vegetables in Illinois in 1899, and the value of the products amounted to \$10,346,797, this being the fourth largest valuation of such products for all the states. The average valuation of vegetables was \$42.09 per acre, while that of all crops taken together was but \$10.04. Altho the gardening industry in Illinois, and especially in Cook county and counties adjoining, has greatly increased since 1899, the figures for that year serve to indicate the relatively great importance of vegetable-growing in Illinois.

Chicago is the principal center of the truck-garden industry of this state, and for a distance of 12 to 18 miles north, south, and west of the city, agriculture is almost wholly gardening. This area is especially well adapted to such farming, as the more or less sandy character of the soil permits early tillage—a very important fact from the truck gardener's point of view, since it enables him to get his products on the market at an early date, while prices are still high. Cook county growers have a market close at hand, so that they can personally dispose of their produce, making sales from their own wagons, thus avoiding freight and commission charges. Further, Chicago affords an ample supply of manure for continuous fertilization, which is absolutely necessary where such intensive farming is practiced, and where so much is taken from the soil each year.

Another important consideration is the labor supply; for such crops as onions and cucumbers require large numbers of laborers at certain times of the year, and in isolated localities and in small towns there is usually insufficient help in the busiest parts of the season. In Cook county, however, the city of Chicago can usually furnish all the labor required, and at a cheaper rate than in remote localities.

Probably the most important garden product of Illinois is the potato. The area in this crop in Illinois in 1899 was 139,464 acres, and the estimated value of the product was \$4,702,033. In Cook county alone there were 15,336 acres in potatoes. Onions and cabbage are important crops, as are also asparagus, celery, beets, and that class of vegetables known as general truck, which includes radishes, lettuce, parsnips, carrots, rhubarb, beans, etc. The growing

of sweet corn, tomatoes, beans and peas for canning, and of cucumbers for pickling, is becoming a prominent industry, and the same is true of melon-growing in many parts of the state. Cucumbers, tomatoes, lettuce, and radishes are extensively grown in hothouses, as well as out-of-doors.

The gardening regions are more or less divided into areas in each of which a certain class of products is cultivated. For example, a strip of ground half a mile or a mile in width may be used for onion culture almost exclusively, or it may be in potatoes or cabbage, or both, or it may be devoted to general gardening.

The more intensive the culture of a crop, the more important becomes the control of its insect enemies. Land is especially desirable for vegetable gardens near the market centers, and as these are almost invariably large cities, such land has a high value, and the greatest possible returns must be realized from it. To insure this the control of injurious insects becomes of great, if not prime, importance.

GENERAL FARM METHODS FOR THE CONTROL OF INSECTS

Clean Culture.—Probably the most valuable of all farm practices for the control of insects is clean culture, by which is meant the clearing away of all useless vegetation, and the numerous other general measures which leave for insects no sufficient winter shelter, or adequate protection from the weather, the birds, and other natural checks upon their numbers. In fall, rubbish of every kind, and especially standing unmarketable cabbages and onions, should be collected and destroyed, to deprive insects of their breeding and hiding places. These methods are particularly helpful in destroying cabbage and onion maggots, cutworms, thrips, plant-lice, potato-beetles, and striped cucumber-beetles. In the summer likewise, and especially early in spring, it is important to keep down the weeds, for they promote a rapid multiplication of insects, and provide temporary breeding places for some species pending the appearance of their special garden food-plants. An early cutting of weeds is further beneficial by preventing their seeding.

Importance of Healthy and Vigorous Plants.—It is a common observation that healthy and vigorous plants withstand the attacks of insects much better than weak and neglected ones. One of the principal requirements for vigorous growth is fertility of the soil. Good seed is necessarily an important item, and, further, it should be properly planted and the crop should be thoroly cultivated to secure strong and healthy plants. Such plants will also endure the effects of drouth for a much longer time than weaker plants.

Rotation of Crops.—Crop rotation is one of the most valuable of the cultural methods for preventing insect attack. As a rule, it

is bad practice in truck-gardening to grow two successive crops of a vegetable, or of nearly related vegetables, successively, on the same piece of land; and, further, a crop should be planted as far as possible from the location of the same vegetable the year before. Especially is rotation desirable when the crop was badly damaged by insects the previous year. Some of the more important insects whose injuries may be checked or controlled by this method, are cabbage and onion maggots, potato-beetles, wireworms, white-grubs, and cutworms.

Fall Plowing.—Another important means of insect control is fall plowing. In the northern part of Illinois, where the winters are usually severe, the value of this measure seems considerable, for its main object is to bring the insects in the soil nearer to the surface, where they may be killed by the cold. It is necessary in such localities to plow as late in fall as possible, when the insects are more or less inactive and unable to go very deep into the ground. Disking and harrowing in the fall is often helpful.

Time of Planting.—It is often possible to avoid insect attack by either early or late spring planting. The object in planting early is to have the crop well started and sufficiently advanced to withstand insect attack when it occurs; while the object of late planting is to bring the crop on after the disappearance of the insect likely to injure it. I have known of but one instance of such benefit derived from early planting, and this was in the case of the onion-maggot. Late spring planting is a successful measure of protection against some insects, such as cutworms, the striped cucumber-beetle, flea-beetles, etc.

Early Detection of the Presence of Insect Pests.—Usually an insect has already done much damage to a crop before its presence is known, and often it is discovered too late for the successful application of remedies. This makes it necessary for the gardener to keep vigilant watch of his crops in order to know when to spray or otherwise to treat them; that is to say, he should detect the presence of an injurious insect in his garden almost as soon as it appears.

Insect injury may be recognized by the actual detection of the culprit; by the failure of seed to germinate; by injury to the leaves; by a wilting of the plants; by the wilting or curling of the leaves, caused by aphid attack; by an uneven stand; or by the slow growth of the plants.

The more important insects known to be injuring garden products in Illinois will now be discussed under the various crops, taken up in alphabetical order. Methods of preparing the principal insecticides used by the gardener are given at the end of the article.

ASPARAGUS

The area in asparagus has greatly increased in Illinois in the last few years, and the plant is now one of the most important products of several gardening districts. Only one insect—the common asparagus-beetle (*Crioceris asparagi* Linn.) has been found doing any considerable damage to this crop, and this in only two localities.* Where present, however, it is an important pest of this plant.



Fig. 1. Common Asparagus-beetle, *Crioceris asparagi*, larvæ and adults, on asparagus. Natural size. (Chittenden.)

and the increasing acreage in asparagus may cause its spread over a much larger territory. The asparagus grower should be on the continual lookout for it, and at its first appearance take immediate measures for its control.

*Since the above was written it has been found in other localities, and it is probably only a matter of a few years until it will become common thruout our asparagus-growing districts.

THE COMMON ASPARAGUS-BEETLE

Crioceris asparagi Linn.

Both beetles and larvæ of this species cause injury by feeding on the young shoots as they appear above ground, and by defoliating the plants later in the season. In the first case the young shoots are rendered unsalable or of poor quality, while the loss of foliage greatly weakens the plants, especially seedlings.

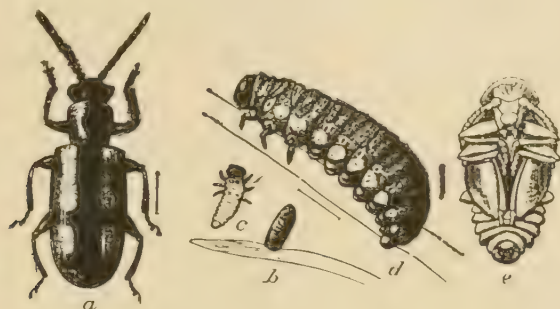


Fig. 2. Common Asparagus-beetle, *Crioceris asparagi*: a, beetle; b, egg; c, newly hatched larva; d, full-grown larva; e, pupa. Enlarged as indicated. (Chittenden.)

The beetle (Fig. 2, a) is one-sixth to one-fourth of an inch in length, and is gaily colored, the thorax being reddish, and the elytra, or wing-covers, more or less striped with lemon-yellow and dark blue, and having a reddish border. Early in spring, at the time of the first cutting of asparagus, the beetles emerge from their winter quarters and lay their conspicuous, yellowish, slender eggs (Fig. 2, b) end to end, in rows of eight or less, on the stalks or leaves of the asparagus plants. In our experiments a single female, in confinement with a male beetle, laid a total of 386 eggs during her life of 29 days—from May 13 to June 11. In about a week the eggs hatch into “grubs,” or larvæ (Fig. 2, c), which immediately begin to feed. These become full grown (Fig. 2, d) in about two weeks, or less, at which time they are a quarter of an inch in length, or slightly shorter, fleshy, and of an olive color. The mature larvæ go into the earth and change to pupæ (Fig. 2, e) just beneath the surface.

They remain in this condition nine to twelve days, and then change to beetles, which, in turn, come out of the ground and lay eggs for a second generation. The beetles of this generation go into hibernation in the fall, about the middle of September in ordinary seasons. It is not certain that there are but two broods a year in Illinois; the life history has not been completely worked out for this state, but observations made in northern Illinois indicate that in ordinary seasons from two to three broods occur there. We have

succeeded in raising three broods in one season in confinement, under what were probably optimum conditions, in the latitude of Chicago.

Methods of Control.—Volunteer asparagus plants should be kept down in early spring, as they afford a good breeding place for the larvæ. Since the shoots are cut for the market every day or two, the eggs which may be deposited on them do not have time to hatch; and if the volunteer growth is kept down there will be little chance of any eggs hatching in the field.

Fresh air-slaked lime, dusted on the plants early in the morning, while the dew is on, has been reported by Dr. F. H. Chittenden as destructive to all grubs with which it comes in contact.

Arsenical poisons are of value upon plants that are not being cut for food, and possess the advantage of destroying beetles, as well as grubs. The application should be made at frequent intervals, or as often as the larvæ reappear. Arsenate of lead or Paris green in water are excellent sprays for this purpose. Dry arsenicals are also effective—as Paris green mixed with lime, with lime and flour, or with land-plaster.

CABBAGE AND CAULIFLOWER

In Cook county gardens, cabbage and cauliflower rank in importance with such garden products as onions, cucumbers, and potatoes. Not only are they among the most generally grown vegetables, but they are peculiarly susceptible to insect attack. In Illinois I have found the following insects doing noticeable damage to these crops: the imported or green cabbage-worm, cutworms, the root-maggot, plant-lice, and flea-beetles.

THE IMPORTED CABBAGE-WORM

Pontia rapæ Linn.

(*Pieris rapæ*)

There is not a gardener who is unfamiliar with this common and destructive caterpillar. There are several "cabbage-worms," but the commonest is the larva of the white butterfly (*Pontia rapæ*) always to be found flying around cabbages in the summer. It emerges early in spring, having passed the winter in the chrysalis or pupa stage. The greenish eggs, small, slender, and ribbed, are soon deposited, usually singly, on the leaves of early cabbages or other cruciferous plants. The velvety green larva (Fig. 3, *a*) begins to feed ravenously on the leaves immediately upon hatching. It gets its growth in ten to fourteen days and becomes a chrysalis (Fig. 3, *b*), changing to a white butterfly (Fig. 4 and 5) some eight to twelve

days later. The length of the season and other general conditions have much influence in determining the number of generations in



Fig. 3. Cabbage Butterfly, *Pontia rapæ*: a, larva; b, pupa.
Natural size.

any year. There are certainly as many as three, on an average, in northern Illinois.

These caterpillars are not only injurious to cabbage, cauliflower, and other cruciferous plants, but they sometimes do much damage to lettuce.



Fig. 4. Cabbage Butterfly, *Pontia rapæ*, male, natural size.



Fig. 5. Cabbage Butterfly, *Pontia rapæ*, female, natural size.

Parasites.—There is hardly a field of cabbage or cauliflower infested with these green caterpillars in which we can not find masses of small white or yellowish cocoons. These cocoons are formed by small larvæ which live within the bodies of the cabbage-worms, soon

killing their hosts. Minute wasp-like adults emerge from the cocoons, and deposit eggs in the bodies of other cabbage-worms. This parasite (*Apanteles glomeratus*) is a valuable friend to the cabbage and cauliflower grower, and it is sometimes abundant enough to free the field of cabbage-worms, at least for the time being. Many gardeners make the serious mistake of destroying the cocoons of this parasite, believing them to be the eggs of the white butterfly.

Another parasite, *Pteromalus puparum*, kills many pupæ, or chrysalides, of this cabbage-worm, and materially decreases the number of the next generation. Often the chrysalides from which the butterfly should have emerged, are dark brownish to black, and when broken open will be found to contain many maggot-like larvæ or dark brown pupæ. These have developed from eggs deposited in the living chrysalides by adults of *Pteromalus puparum*, which, like the parasite of the larvæ, is a small wasp-like insect. I have reared 48 to 58 of these parasites from single chrysalides.

In one large gardening district where cabbage and cauliflower are grown extensively, I could not find a single living worm or chrysalis August 26, 1908, altho a few weeks before both had been abundant. All had been killed by their parasites.

Remedial Measures.—The following remedies are equally effective for any of the several caterpillars feeding on cabbage leaves, with the exception of cutworms, which will be treated later.

The use of arsenicals on cabbage and cauliflower is often discouraged because of the supposed danger to the consumer. Experiments with arsenate of lead and Paris green have been made, both in New York and in Kentucky, in which the sprayed plants were analyzed to determine the amount of poison remaining on them. It was found that only a slight trace, if any, was present—in no case enough to be dangerous, even if all were consumed by one person. Cauliflower, however, should not be sprayed after the "flower" has begun to form, nor should cabbages be sprayed after they are two-thirds grown.

Paris green is one of the standard remedies, and is more used today in spraying for cabbage-worms than any other insecticide. It may be applied dry or suspended in water, and specific directions for either use of it are given at the end of this article (pages 149-150). A resin-lime mixture has been highly recommended by Mr. F. A. Sirrine,* who, after experiments with it, concluded that the yield of cabbages was increased 60 to 100 percent by the treatment. He figures the cost of it at about \$2.00 an acre. Two applications are usually sufficient. Directions for the preparation of this mixture also may be found on page 150.

*A Spraying Mixture for Cauliflower and Cabbage-worms. Bull. N. Y. Agr. Exper. Station, No. 144 (Sept., 1898). Geneva.

Arsenate of lead has been successfully used against the cabbage-worm, but has the disadvantage of not adhering as well as the resin-lime mixture, altho better than Paris green alone. It must consequently be applied oftener—sometimes as many as three or four times a year, but ordinarily only twice. It has the advantage of being easy to prepare, and, as it is white, one can easily see when the plants have been thoroly sprayed.

Pyrethrum is also recommended for this insect. It is more expensive than the arsenicals, but has the two advantages over them that it is not injurious to man, and that it can be used later in the season than they—that is, when the heads are nearly formed.

Hot water at nearly boiling point will, of course, kill the worms, and is said to be harmless to the plants. Lime has been used against these worms, but it is ineffective, especially when they are numerous. Professor J. W. Lloyd says* “Cabbage-worms were abundant late in the season, and in spite of five applications of air-slaked lime did considerable damage to the crop.”

Cabbage stalks and other debris should be removed from the field in fall and burned, unless, as recommended by Dr. F. H. Chittenden,† a few of the plants are left and poisoned as bait for the last generation of the insects.

THE VARIEGATED CUTWORM

Peridroma margaritosa Haw.

(*Agrotis saucia*, *Peridroma saucia*)

Cutworms are sometimes very injurious to cabbage, cutting off the young plants and killing them outright. For this reason they are a worse pest than the green caterpillars; but they are not so widespread, and are therefore of less economic importance. The life history of the above species and a description of it are given in connection with insects affecting lettuce (pages 129-130).

Remedies.—Poisoned bait (see page 131) is probably the best remedy for cutworms. If they are known to be present, the bait should be put on the prepared field just before the cabbage plants are set out. If not, it should be used as soon as the presence of cutworms is recognized.

Spraying with an arsenical poison, such as Paris green, will destroy some of the insects if the spray is applied to the stems near the ground; but the stalks are probably more frequently cut off just below the surface of the ground than just above it, and in the former case the poison would not be eaten by the cutworms.

The collection of cutworms by hand is advised for some crops, but it would generally be too expensive for large cabbage fields.

*The Farmer's Vegetable Garden. Bull. Ill. Agr. Exper. Station, No. 105 (Feb., 1906), p. 190.

†Insects Injurious to Vegetables, p. 139. Orange Judd Co., New York. 1907

THE CABBAGE ROOT-MAGGOT

Phorbia brassicæ Bouché*(Pegomyia brassicæ, Anthomyia brassicæ)*

One of the most destructive enemies of cabbage and cauliflower in Illinois is the cabbage root-maggot. It is white or cream colored, resembling the onion-maggot (Fig. 26), which is known to all Illinois gardeners. It is one of the immature stages of a fly which is much like the house-fly in appearance, but more cylindrical, somewhat smaller, and of a grayish or brownish color. The winter may be passed in either the adult, puparium, or maggot stage, the flies hibernating in rubbish, buildings, or any accessible place that will afford shelter, the puparia in onion bulbs left in the fields in the soil, and the maggots in the refuse bulbs. Early in spring the flies deposit their small, elliptical white eggs in small cracks and crevices near the stem of the plant, or on the stem beneath the surface. Usually within a week—not so soon if the weather is cool, but often within 24 or 36 hours in the warmer parts of the year—small maggots hatch from the eggs, and immediately go into the ground and begin to feed on the roots or stalk. Becoming full grown in a few weeks, they leave the roots to pupate in the soil near by. They remain in this dormant stage, as oval brown puparia, for about two weeks (in summer), and from these the adult flies emerge. There may be two or more generations in Illinois, according to the length of the season.

Most of the injury to cabbage and cauliflower by this maggot is done while the plants are small, and particularly to early cabbage. For this reason the acreage of early cabbage has greatly decreased in this state within the last few years.

Economic Control.—Many methods have been recommended by various writers for the control of the cabbage root-maggot, but most of these are preventive rather than remedial. Cabbage seldom brings a high price, and many measures that have been proposed are impracticable because of their cost.

For the *prevention of maggot attack in seed beds*, probably the most successful and practical method of protecting the young plants is that of screening them, as suggested by Dr. James Fletcher,* and later successfully demonstrated on a large scale by Mr. W. J. Schoene.† This consists in growing the seedlings under cheap frames, made of light wood and covered with cheese-cloth (Fig. 6), to protect the plants from the cabbage-maggot flies. In Mr. Schoene's experiments it proved very successful. He says: "Plants

*Insects Injurious to Grain and Fodder Crops, Root Crops, and Vegetables. Bull. Central Experimental Farms, Ottawa, Canada, No. 52 (June, 1905), p. 35.

†Screenings for the Protection of Cabbage Seed Beds. Bull. N. Y. Agr. Exper. Station, No. 301 (March, 1908). Geneva.

raised under cloth grew faster and reached the desired size for transplanting one week before the seedlings in the check [untreated] area. The screened sets were seasoned by the removal of the covering thirteen days before the time of replanting, and showed no more wilting when transplanted than did the check seedlings."

"The screened bed was entirely free of maggots, and produced 50,000 sets, which were replanted. The check bed, of more than



Fig. 6. Cabbage seed-bed with frame and screening in position, to keep out the Cabbage Root-maggot, *Phorbia brassicae*. (New York Experiment Station.)

three times the size, yielded only 30,000 desirable plants. The cabbage maggots were generally very destructive to unprotected seedlings."

The total cost for material was approximately 40 cents for each 1,000 plants. The screens not only protect the plants from maggots, but also from the flea-beetles, which often do much damage to young cabbage.

For the *destruction of maggots at the time when seedlings are to be transplanted*, roots not too badly infested for use should either be washed off with water before resetting them, in order to remove the maggots, or, as Professor F. L. Washburn suggests,* they may be dipped in a decoction of white hellebore—one part of the powder to two parts of water. The latter treatment is preferable, for while

*The Cabbage Maggot and other Injurious Insects of 1906. Bull. Minn. Agr. Exper. Station, No. 100 (Dec., 1906), p. 12. St. Anthony Park.

the water will have no effect on the maggots except to remove some of them, the hellebore may kill them all.

For the *prevention of maggot attack after transplanting*, probably the most successful measure is the use of tarred-paper cards. Those ordinarily used are made of a thin grade of tarred felt-paper, and are about two and a half inches in diameter. They may be of any shape, but, as a matter of economy, are usually hexagonal, with a slit from one side to the center. The card is placed on the plant by separating the two edges of the slit and slipping the card around the plant so that the stem comes in the middle of the card. The card must then be pressed close to the stem and flat on the ground. This being done, the female fly must lay her eggs either on the card—where there is small chance of their hatching—or on the stem—and if the card is close to the stem the young larvæ hatching from them will be unable to reach the roots—or else on the ground beyond the card, in which case the young larvæ, hatching so far from the plant, would probably be unable to reach it.

A carbolic acid and lime mixture (see page 155) has been recommended by others, but in our experience it proved worthless, the coat of lime cracking and leaving places for the deposit of eggs. After 24 hours the carbolic acid loses its value as a repellent. The mixture is applied along the rows with a sprinkling-can or spray-nozzle as the plants are transplanted, and in such manner as to coat the entire surface thinly around the plants.

Tobacco dust placed around the base of the plants has been found to prevent the female from depositing her eggs on or near them.

When these maggots have once gained a foothold in a cabbage field it is difficult, if not impossible, to exterminate them. The only practical insecticides which have been recommended are the carbolic acid emulsion, a decoction of hellebore, and carbon bisulfid (see pages 153, 154 and 158), and these have given quite variable results. The carbon bisulfid has been used with success, but the expense of application prohibits its use in large commercial gardens. Hellebore decoction has given us very good results. A third of a pint should be poured at the base of each plant when transplanted, and each week thereafter for three or four weeks.

In using these insecticides it is necessary to make thoro application at the base of the plants before the maggots have had a chance to enter the root and protect themselves.

The application of commercial fertilizers is of much value. They stimulate the plant and make it more resistant to maggot attacks.

Clean farming and fall plowing aid in preventing maggot attack.

The use of "blood and bone," with hellebore, was suggested to us by a gardener, who reported that some of his cabbages had been protected from this maggot by this means, while plants not so treated were seriously damaged by it, as in previous years. We tried this material this year (1910), placing a small quantity of the dry mixture about each cabbage plant after transplanting to the field, but, unfortunately for the test, the maggots were not present in injurious numbers either in the treated or untreated plots, and therefore no definite conclusions were reached. Upon examining the "blood and bone" around the plants, however, we found in it many maggots which were bred to adults and determined as *Phorbia fusciceps* Zett.—a species closely related to the cabbage and onion maggots, and often injurious to the same crops. The same species infested "blood and bone" when applied to onions, the mixture being in this case drilled in on each side of the row. Altho no recommendations can be made from these tests, it is thought best to make brief record of them.

THE CABBAGE PLANT-LOUSE

Aphis brassicae Linn.

During midsummer or early fall this plant-louse becomes noticeably abundant on cabbage and cauliflower plants, usually infesting the under sides of the leaves in large, packed colonies, which rapidly

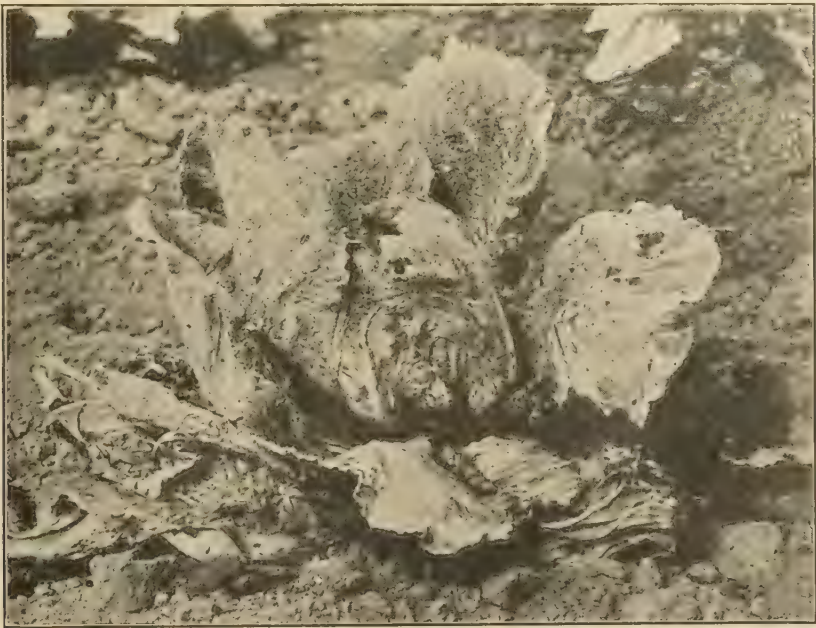


Fig. 7. Cabbage Plant-louse, *Aphis brassicae*, on head of cabbage.

increase in size unless checked by enemies or unfavorable weather. Both wingless and winged individuals are to be found, and though there are few of the latter as compared with the multitudes of the former, these few winged lice are the chief means of starting colonies in uninfested fields. Like other plant-lice, the cabbage louse gives birth during the summer months to living young, without previous fertilization of the female by the male. In the fall, as observed by Fletcher, Garman, Quaintance, and others, both sexes are produced, and eggs are deposited on the stems and leaves of cabbages remaining in the field. Sometimes, however, viviparous females are found as late as midwinter, within the cabbage heads.

The lice are about the size of a pin-head, soft-bodied, pale greenish, but completely covered with a whitish powder or bloom which is not unlike the bloom on cabbage leaves.

Plant-lice injure cabbage by sucking the juices of the plant. When abundant, they so disfigure and stunt it, especially the smaller and weaker plants, that it becomes unfit for market.

Natural Checks.—If it were not for the natural checks on its increase, the cabbage plant-louse would be one of the very worst pests with which the cabbage grower has to deal; but wet weather and its insect enemies greatly restrict its multiplication. It is not only subject to attack by many minute parasites, but it is preyed upon by several kinds of “ladybird” beetles and by the larva of a lacewing fly (*Chrysopa*), whose combined attacks greatly lessen the numbers of the aphids, and hold them in check.

Remedies.—Probably the most successful method of dealing with the cabbage-louse is fumigation with carbon bisulfid. This substance was tested by us in the fall of 1908 on cabbages badly infested with plant-lice. Fumigation of cabbage or cauliflower on a commercial scale with individual covers for the plants would be too expensive for profit; but an economical method is to cover a considerable area of plants with large canvas or muslin sheets, with props at the corners and center, and wherever else may be necessary.* The cover being ready, dishes are placed beneath it containing the carbon bisulfid at the rate of a teaspoonful to each cubic foot of space. The edges of the cloth, which should lie on the ground, are covered with earth to prevent, as far as possible, the escape of the fumes. After forty-five minutes to an hour the cover may be removed. This treatment also killed the thrips and cabbage-worms which infested the plants, but it did not kill the parasites concealed in the aphid skins—which fact is greatly in its favor. With exposures of 20 and 30 minutes, nearly all of the lice were killed; but with only 15 minutes or less, practically none were

*The Melon-louse and other Aphids, by C. E. Sanborn. Bull. Texas Agr. Exper. Station, No. 89, (not dated) page 47. College Station.

killed. (For other particulars concerning the use of carbon bisulfid see page 158.) Mr. C. E. Sanborn* has recommended the use of "Aphis Punk" or "Nico-Fume" paper in fumigating plants under cover.

Kerosene emulsion of a 10 percent strength is the standard spray for the cabbage plant-louse. Care should be taken to spray thoroly the under side of the leaves, where the lice are usually most abundant, for the liquid must come in contact with the insects in order to kill them. (For formula, etc., see page 153.)

Tobacco decoction and various soap mixtures have been recommended for this plant-louse, but they are less effective than the kerosene emulsion. It is hardly necessary to say that treatment should begin at the first appearance of the lice.

Clean culture, especially the destruction of the cabbage and cauliflower stalks in fall, is very important, to destroy the eggs which are deposited on the cabbage and related plants, and likewise to destroy the young and adult lice which may be hibernating on the same kinds of plants.

THE CABBAGE FLEA-BEETLE

Phyllotreta vittata Fabr.

This flea-beetle, often very abundant and destructive, is the only one of the many flea-beetles—so named because of their remarkable leaping ability—which has been found injuring cabbage in northern Illinois. It is a black, shining oval beetle (Fig. 8, *a*)

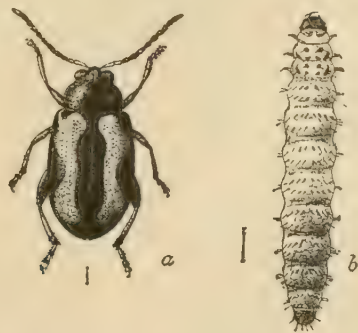


Fig. 8. Cabbage Flea-beetle, *Phyllotreta vittata*: *a*, beetle; *b*, larva. Enlarged as indicated.

about .08 inch long, with a broad, wavy longitudinal marking of pale yellow on each wing-cover. It sometimes injures other crops, especially radishes, and its food plants include many weeds. It injures plants by eating innumerable holes and pits in the leaves.

*Loc. cit.

It is most destructive to cabbages early in the year, when the plants are less than two inches high, at which stage they easily succumb to such attacks.

I quote in full the concise paragraph on the life history of the immature stages of this flea-beetle given by Professor H. Garman.*

"The early history of the cabbage flea-beetle was made out in 1865 by Dr. Shimer, of Mt. Carroll, Illinois. He found that the larva [Fig. 8, *b*] feeds on the roots of cabbage, in which respect it is different from a very similar European beetle, and also from the next one [*P. sinuata*] treated in this paper, both of them being leaf-miners. The eggs of this beetle are placed at the base of the plant. The grubs hatching from them work their way into the earth, mining and feeding on the roots, in some cases completely destroying the plants. When fully grown they are about one-fifth inch long, yellowish white in general color, the head dark brown. They desert the roots when ready to change to pupæ, and pushing into the earth a short distance, make a small cell, in which the change takes place."

Prevention and Remedies.—A useful method of preventing flea-beetle attack recommended by Mr. W. J. Schoene,† consists in screening the seed beds, as described on page 108 for the protection of seedlings against the attacks of the cabbage root-maggot. The most effective treatment is spraying with Paris green or arsenate of lead, using Bordeaux mixture as a diluent (see pages 151 and 152). To use Bordeaux is not absolutely necessary, but as it is a powerful repellent it adds to the value of the spray.

Many other remedial measures have been recommended, such as powdering the plants with air-slaked lime, soot, road dust, wood ashes, tobacco dust, etc., these substances acting as repellents, or with Paris green and lime—tho the latter mixture is more effective as a liquid spray; and spraying kerosene emulsion around the base of the plants is said to destroy the eggs and young larvæ of this insect.

Cultural Methods.—As this flea-beetle feeds on many weeds, especially the crucifers, all weeds in the immediate vicinity of the garden should be destroyed.

CUCUMBER AND MELON

Cucumbers and melons are among the most important garden products in Illinois. In 1899, 2,580 acres were devoted to cucumbers, and 466,876 bushels were marketed. This report does not include cucumbers grown thruout the state under many hundred

*Insects Injurious to Cabbage. Bull. Ky. Agr. Exper. Station, No. 114 (June, 1904), p. 37. Lexington.

†Bull. New York Agr. Exper. Station, No. 301 (March, 1908), p. 170. Geneva.

thousands of square feet of glass. The same year there were 10,963 acres in watermelons and muskmelons in Illinois. The acreage in both these crops has greatly increased since 1899.

The most important insect enemies of these plants are, outdoors, the striped cucumber-beetle, the squash-bug, and the melon aphid; and, in greenhouses, thrips and the white-fly. Altho they are not insects, two other greenhouse pests should be mentioned, namely, the red spider, and a nematode worm commonly known as the eel-worm.

THE STRIPED CUCUMBER-BEETLE

Diabrotica vittata Fabr.

Ordinarily this is a pest which the gardener must carefully guard against. As the young cucumber, melon, or other cucurbitaceous plants make their appearance above ground, they are attacked by these ravenous beetles, and large areas may be killed by them in a few days.

The beetle (Fig. 9, *a*) is small (about two-fifths of an inch long), with black head, yellowish thorax, and yellowish wing-

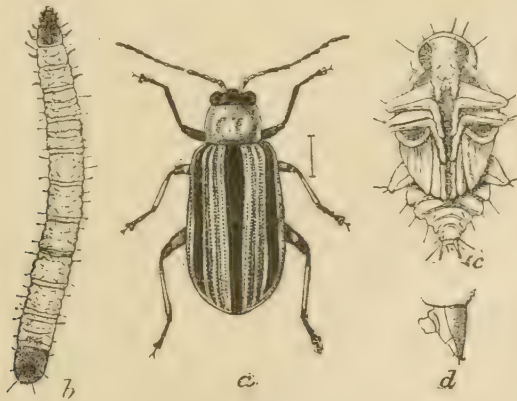


Fig. 9. Striped Cucumber-beetle, *Diabrotica vittata*: *a*, beetle; *b*, larva; *c*, pupa; *d*, tip of larva, side view. Enlarged as indicated.

covers, marked lengthwise with three black stripes. It passes the winter in the ground or beneath boards or similar shelter, and as the young food plants appear above ground—usually about the first week in June—it comes forth and feeds on their leaves. If the beetles are at all abundant they may soon devour the small, tender plants. They feed continuously and voraciously for a week or ten days, and then commence to pair. The eggs (Fig. 10) are deposited singly, and may usually be found on the under surface of the leaf, on the stem near its base, or on the ground near the plant. The larvæ (Fig. 9, *b*, *d*) upon hatching, feed within the stalks or

on the roots, or sometimes on the fruit and vines as they lie upon the ground. The length of the larval period no doubt varies greatly, depending on the food supply and climatic conditions. The pupa (Fig. 9, c) is formed in an earthen cell in the soil, and the transformation to the adult beetle is completed within 7 to 14 days. Altho the beetles of this new generation begin to emerge the latter part of July, they may continue to appear thruout August. Professor Garman, in his studies of this insect,* found that in con-



Fig. 10. Striped Cucumber-beetle, *Diabrotica vittata*, egg, much enlarged, with portion of surface more highly magnified at right.

finement the entire life cycle of an individual was 26 to 33 days. It is possible that a second generation may appear in the southern part of the state, but in northern Illinois probably but one full generation occurs under normal conditions.

Preventive and Remedial Measures.—A large number and variety of methods for the control of this insect have been recommended, but only those which have given promising results will be discussed. One of the oldest methods for protecting the young plants from the cucumber-beetle is covering them with a screen; but while this is very satisfactory in small gardens, it is not so practicable on a large scale as the use of the Bordeaux mixture in connection with a trap crop, as discussed farther on. It has been found that for a short time in spring, before the beetles begin to pair, they may be killed with a spray of Paris green or arsenate of lead, but that they will not feed readily upon sprayed foliage after pairing, and arsenicals alone can not be generally recommended for the cucumber-beetle without further tests of their efficiency.

The use of squash as a trap crop (Fig. 11) in combination with a spray of Bordeaux mixture or Bordeaux and arsenate of lead on the cucumber plants and an arsenical poison on the squash, is one of the best means of preventing the attacks of these beetles. Mr. F. A. Sirrine has given a very complete account of this method of treatment based on his own experiments, and the following is taken largely from his paper.†

Squash seed is planted around the margin of the field about four days previous to planting it with cucumbers, or other crop.‡ At

**Enemies of Cucumbers and Related Plants.* Bull. Ky. Agr. Exper. Station, No. 91 (March 8, 1901), p. 5. Lexington.

†*Combating the Striped Beetle on Cucumbers.* Bull. N. Y. Agr. Exper. Station, No. 158 (May, 1899), pp. 14-16. Geneva.

‡Mr. Sirrine informs us that only the Hubbard or the Boston Marrow squash should be used, these being by far the most attractive to the beetles.



Fig. 11. Cucumber field with squashes along its border to attract the Striped Cucumber-beetle. (New York Experiment Station.)

the time of cucumber-planting there should be a second planting of squash seed on the margins of the field. At the first appearance of the beetles about half the squash-vines should be dusted with some easily obtainable arsenite, and soon after the cucumber plants appear above ground they should be sprayed with Bordeaux mixture, using the 4-4-50 formula (for preparation see page 151). At about the same time the cucumber plants are sprayed with Bordeaux the squash-vines should again be dusted with an arsenite. Two weeks after the cucumber plants have appeared all but a few of the squash plants may be removed. These should be left until the cucumber-vines have set fruit, as the beetles will feed on the squash flowers in preference to those of the cucumber. Sirrine recommends spraying the cucumbers with Bordeaux mixture three times: first, as soon as the seed leaves are exposed; second, when the third true leaf appears; and last, just before the plants commence to vine. He says: "The cost of three applications of the Bordeaux mixture will not exceed \$2.00 per acre; whereas, the cost of wire covers would be \$40.00 per acre, and they probably will not last over three years."

Repellents are effective against this beetle, and Bordeaux mixture is one of the best, altho it is best to use it in connection with a trap crop, as above described. Other much-used repellents are air-slaked lime, land-plaster, sifted ashes, road dust, and tobacco dust, but these are not always effective when the beetles are abundant.

Clean culture will prevent much of the damage usually done by many of the common garden pests, and it is especially effective against the cucumber-beetle. It has been recommended in this connection, that as soon as the crop is harvested the vines be covered with straw and burned. This is a far better practice than that of gathering them up before destroying them, as the latter procedure leaves many of the beetles undisturbed in the field.

THE SQUASH-BUG

Anasa tristis DeGeer

The squash-bug, altho confining its attacks largely to the squash and other plants of the gourd family, is often very injurious to the cucumber in early spring, when emerging from its winter quarters. It finds its way into the cold frames in which the plants are being started, when no other food plant is available.

This large, ill-smelling, dark brown bug (Fig. 12, *a*) hibernates as an adult in rubbish, sheds, and wood-piles, under loose bark on stumps, or in any other available place of protection. In northern Illinois the bugs make their appearance about the middle or the last of June, or even later; but I have found most of their injury

to the cucumber done while the young seedlings are in the cold frames. In all such cases these frames were near wood-piles or out-buildings, and during the occasional warm days of spring, when

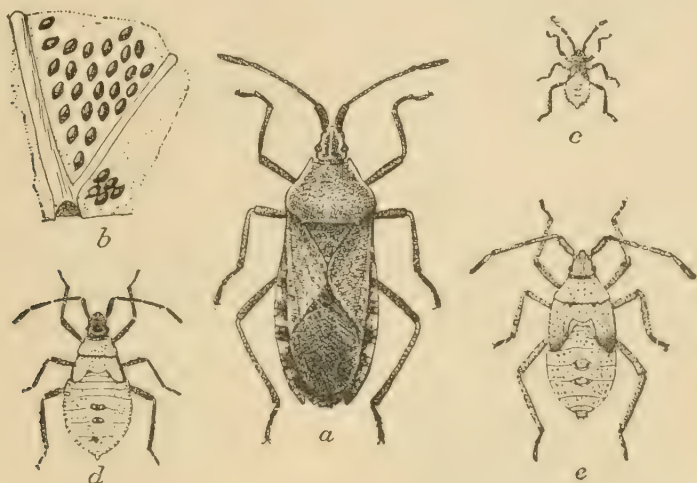


Fig. 12. Squash-bug, *Anasa tristis*: a, adult; b, egg cluster; c, d, e, young in different stages. Twice natural size.

the frames were opened, the bugs gained entrance, the temperature of these beds making them fully active. Shortly after coming from their winter quarters they deposit the conspicuous clusters of glossy yellowish-brown eggs (Fig. 12, b), usually on the under side of the leaves. The young, light gray bugs (Fig. 12, c) hatching from these, immediately begin sucking the juices of the plants. In their later immature stages (Fig. 12, d, e)—which differ only in size from the young bug as it hatches from the egg—they feed, as do the adults, upon the juices of the plant. The loss of sap, however, is not the primary cause of the wilting of the plants. This is due principally, if not wholly, to a liquid poison which the bug introduces into the wound which it makes. In some cases it also gives entrance to a bacillus which causes a wilt disease.

Methods of Control.—Collecting the bugs under board traps is probably the most satisfactory of the various methods suggested for the control of this pest. This should be done in early spring, as soon as the bugs appear. The boards are simply laid on the ground as a decoy shelter for them during the night, and here they may be easily captured early in the morning. The eggs should likewise be collected and destroyed as fast as they are laid on the leaves.

Kerosene emulsion kills the young bugs without injuring the plants if it is very carefully applied, but it is too dangerous for ordinary use.

Here, again, clean-farming methods are of much importance. Cold frames should be placed at some distance from wood-piles and out-buildings, and as soon as the crop has been gathered the vines should be covered with straw or other easily inflammable material and burned.

THE MELON APHIS

Aphis gossypii Glover

(*Aphis cucumeris*)

Altho the truck gardener may not have noticed the melon aphis on his cucumber plants, a curling of the leaves (Fig. 13) is presumptive evidence of its presence in injurious numbers. It is not only a serious outdoor pest, but it is often very injurious to cucumbers in greenhouses.



Fig. 13. Melon Aphis, *Aphis gossypii*; its work. (Chittenden.)

This plant-louse (Fig. 14) varies in color from pale yellowish to blackish green. Its life history and insect enemies are very similar to those of many other plant-lice, such as the one which has already been discussed as a cabbage insect (page 111). Briefly, the melon aphid appears on cucumber and melon plants early in the



Fig. 14. Melon Aphid, *Aphis gossypii*: *a*, winged female; *aa*, enlarged antenna of same; *ab*, dark female, side view; *b*, young nymph or larva; *c*, last stage of nymph; *d*, wingless female,—all greatly enlarged.

season, and increases rapidly in numbers during the summer unless checked by its insect enemies or by unfavorable weather. It is still doubtful whether it ever produces eggs to carry the species over winter, but it is known that viviparous females—the form found thruout the summer—may hibernate in some parts of Illinois.

Remedial Measures.—The measures recommended for the control of the cabbage-louse (pages 112-113) may be used against the melon aphid, and of these, fumigation with carbon bisulfid is doubtless the most efficient.

Owing to the large number of its food plants, clean culture is especially important in dealing with the melon aphid, particularly the cutting and burning of weeds and old vines; and fall plowing is also advisable.

In greenhouses, fumigation with hydrocyanic acid gas is doubtless the best treatment for this insect. The procedure is described on pages 156-158.

THE GREENHOUSE WHITE-FLY

Aleyrodes vaporariorum Westwood

One of the most troublesome and destructive insects with which the greenhouse vegetable-gardener must deal is the white-fly. This little pest attacks cucumbers, tomatoes, peppers, and lettuce under glass, and a considerable variety of flowering and ornamental plants.

The winged adult (Fig. 16) is about .06 (one seventeenth) of an inch in length, and looks as if dusted with flour. The minute

irregularly ovoid eggs are deposited on the under surface of the leaves, to which each is attached by a very short, slender stalk.



Fig. 15. White-fly, *Alcyrodes vaporariorum*, nymphs on leaf. Twice natural size. (Connecticut Experiment Station.)

Recently hatched larvæ are flat, oval in outline, and transparent or translucent according to age. They settle on the leaf close to the empty egg-shells, soon attach themselves, and there remain (Fig. 15), molting four times and becoming adult with the last molt. The entire life cycle of the white-fly from the time the egg is de-



Fig. 16. White-fly, *Alcyrodes vaporariorum*, adults on leaf. Twice natural size. (Connecticut Experiment Station.)

posited until the adult emerges, is completed in a month to five and a half weeks, at the ordinary greenhouse temperature in summer.

The larvæ and pupæ secrete a honeydew which falls on the leaves below them; and on badly infested plants, where this liquid

becomes abundant, a sooty fungous growth appears on the leaves covered with it, which hastens the death of the plants.

Parasites.—In the university greenhouse, at Urbana, many of the plants, especially *Salvia* and pansy-geranium, were badly infested in the midwinter of 1908 by the little white-fly, but two months later these insects were found to have been almost exterminated by a minute hymenopterous parasite, which proved to be a new species, and has since been described by Mr. A. A. Girault as *Encarsia versicolor*.* It attacks the immature forms of the white-fly, and the infested young may be recognized by their black color, those not infested being pale greenish.

Remedies.—Fumigation with hydrocyanic acid gas is by far the most efficient means known for controlling the white-fly in greenhouses. In ordinary greenhouses it may be used at a strength of one ounce of cyanide of potassium to 3,000 cubic feet of space. In new tightly built houses a smaller quantity may be used; but in very loosely built or weather-shrunk houses more must be used. The mode of using this gas is described on pages 156-158. It is commonly necessary to fumigate three or four times, at intervals of about two weeks.

Fumigation with tobacco stems, or with any of the commercial tobacco extracts, is partially effective against this insect, and where the use of hydrocyanic acid gas is impracticable this treatment is recommended (pages 159 and 160). More fumigation will be required, but, if persistently followed up, the white-fly can be kept in check by this means.

THE ONION THRIPS

Thrips tabaci Lind.

This insect, which is very injurious to cucumber plants in the greenhouse, is discussed in connection with its injury to the onion (page 137). In the greenhouse its life history is the same as out-of-doors, excepting that the life cycle varies greatly in length under the various artificial conditions which prevail in greenhouses. As a rule, cucumbers are started under glass in fall, and it is at this time that the thrips migrates from outdoor vegetation into the houses. It breeds successfully on almost any kind of greenhouse vegetation, and may soon become well established; but it is not usually until midwinter that it becomes abundant enough to alarm the gardener.

Remedial Measures.—Clean culture is one of the most important means of holding this pest in check. As a rule the grasses

**Encarsia versicolor* species novum, a Eulophid Parasite of the Greenhouse White-fly, *Aleyrodes vaporariorum* Westwood. Psyche, Vol. XV, No. 3 (June, 1908), pp. 53-57. Cambridge, Mass.

and weeds around greenhouses are badly infested with thrips in summer, when the greenhouses are not in use, and on these plants it continues to breed until fall, when the seed heads of such plants as pigweed (*Amarantus retroflexus*), wild sunflower (*Helianthus retroflexus*), and foxtail grass (*Chetochloa viridis*) are filled with winged thrips ready to migrate into the houses. It is very important, consequently, that all weeds should at least be kept down by cutting, tho it is much better to cultivate the land several times during the summer to prevent weeds and grasses from coming up. Cold frames to be used in starting young plants should not be placed near an infested onion field, nor where vegetation is allowed to grow wild.

Spraying and fumigation with tobacco extracts (pages 154 and 159) thruout the fall and winter will hold the thrips in check. The gardener should not wait until his plants are visibly injured, but should continually look for the insect, and as soon as the first thrips is found, should begin operations.

Hydrocyanic acid gas has been used by some with apparent success. In a small greenhouse containing 4,500 cubic feet of space, we were successful in killing 99 percent of the thrips, without injury to the cucumber plants, by using the gas at a strength of one ounce of cyanide of potassium to 2,000 cubic feet. The maximum and minimum temperatures thruout the period of fumigation, which lasted all night, were 74° and 65° F. respectively.

Kerosene and soap emulsions (page 153) are effective against the thrips before the plants have made much foliage, but at a later period it is impossible to spray thoroly under the surface of all the leaves, and as these emulsions kill by contact it is of the greatest importance to reach all the insects.

Dipping the leaves of small plants in a soap solution just before transplanting them to the greenhouses has been found useful when plants become infested in cold frames.

THE RED SPIDER

Tetranychus bimaculatus Harvey

(*Tetranychus telarius*)

This common pest is a tiny mite rather than a true spider. It has been a source of trouble to the indoor cucumber-grower for years, and altho it can usually be kept in check by careful and thoro cultural and spraying methods, it is a veritable pest when it once obtains a foothold. It is a general feeder, and among the outdoor vegetables which it often injures are celery and eggplant.

This mite (Fig. 17 and 18) is so familiar to growers that a brief description will suffice. It is about one-fiftieth of an inch

long, oval, with four pairs of legs, and usually a dark spot on each side. This latter character, however, is not constant. The general color also varies, some mites having a decidedly reddish tint, while others are almost colorless. They spin fine webs over the surface

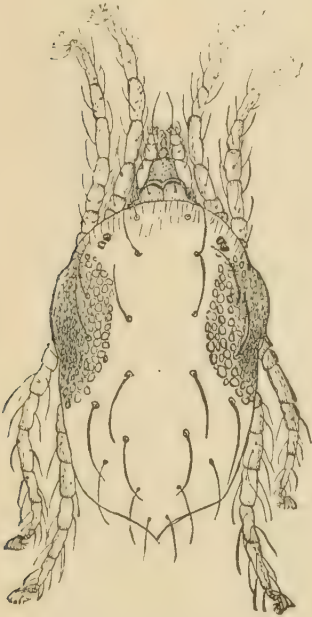


Fig. 17. Red Spider, *Tetranychus bimaculatus*, male, greatly magnified.



Fig. 18. Red Spider, *Tetranychus bimaculatus*, female, greatly magnified.

of the leaf—usually on the under side—beneath which they live, and it is largely for this reason that they are hard to reach. The minute eggs are globular, pale and transparent when deposited, but later change to reddish. They are commonly placed on the under surface of the leaf, but sometimes on other parts of the plant. The young mites mature in about ten or twelve days.

Remedial Measures.—This pest can usually be held in check, or even exterminated, by thoro and timely spraying of the plants with water, if the spray is fine and the pressure considerable; but this is a preventive rather than a remedial measure, for, owing to the excessive rate of multiplication of the mites in a hot, dry atmosphere, and owing further to the fact that the web beneath which they live becomes denser as their numbers increase, the spraying is ineffective unless it is done while the infestation is still slight. Indeed, no treatment is of much practical value if the mites have become well established on living plants. A special nozzle introduced by Dr. B. T. Galloway, of the U. S. Department of Agriculture, for use against the red spider is very effective, "as it

readily serves to keep the leaves in a thoroly healthy condition, and at the same time wets the beds but little.”*

Fumes of sulphur or hydrocyanic acid gas will kill the red spider, but the strength required is by far greater than the plants will stand. After the cucumber or other crop has been gathered, and before infested vines have been removed, it is advisable to fumigate them with one of these two substances, using one ounce of cyanide of potassium to one hundred cubic feet of space, or burning one pound of sulphur to one thousand cubic feet. It is hardly necessary to say that these strengths will kill living plants. (For full directions for the use of these materials, see pages 150 and 159.)

Sulphur is one of the best remedies for the red spider, and most of the remedies that have been recommended require sulphur as one of the ingredients. Liberally dusting the plants with sulphur after syringing is effective, or, better, applying a spray consisting of one ounce of sulphur to one gallon of water. A little soap added to this sulphur solution will increase its efficiency.

Soap solutions, either whale-oil or a neutral soap such as the “Ivory,” are of great value in the eradication of the pest, but the addition of sulphur as mentioned above increases their value.

A lye-sulphur mixture has recently been recommended by Dr. F. H. Chittenden, and is said to be more effective than any of the many other materials tested. Directions for preparing this spray are given on page 155.

Whatever insecticide is used, especially when the infestation is severe, should be applied with as great pressure as practicable, for the greatest trouble in controlling this mite arises from the difficulty in penetrating the web which it spins. The stream should also be directed to the lower surfaces of the leaves, for it is here that the spider is most often found.

THE EEL-WORM

Heterodera radiculicola Greeff

The eel-worm is a common pest in hothouses, particularly injurious to the cucumber, and, unfortunately, it is apparently becom-

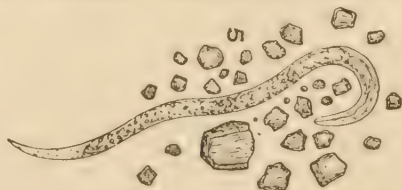


Fig. 19. Nematode worm, *Heterodera radiculicola*, among particles of soil. Greatly magnified. (Massachusetts Experiment Station.)

*The Common Red Spider, by F. H. Chittenden. Circ. U. S. Dept. of Agr., Bur. of Ent., No. 104 (Jan. 26, 1909), p. 8.

ing more widespread each year. In Illinois it is known only as a greenhouse pest, and our observations indicate that here, at least, it is unable to survive the winter in the field.

The only unmistakable indications of the presence of this root feeding worm are the swellings or enlargements of the roots (Fig. 20) often referred to by the gardener as root-knots.* These root-



Fig. 20. Cucumber roots showing galls of a nematode, *Heterodera radiculicola*. (Massachusetts Experiment Station.)

knots vary in size and shape, largely according to the number of worms present, to their position on the roots, and to the kind of plant. The presence of the eel-worms may be indicated by a sickly appearance of the plant, by the dying of its leaves, and by its final collapse, altho nothing but an examination of its roots can certainly

*This deformity should not be confused with the club-root of cabbage and related plants, which is due to bacterial disease.

incriminate the species. Plants are commonly half grown or bearing fruit before they are noticeably weakened by the eel-worm.

The young eel-worm (Fig. 19) is very minute and elongate. It is provided with a spearlike organ projecting from the head, and with this it pierces the tender root (Fig. 21), in which it ultimately embeds itself. The worms continue to grow—in width rather than

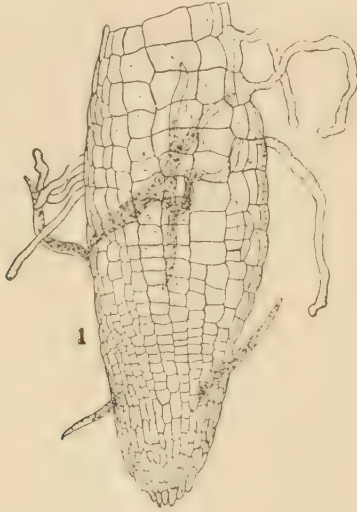


Fig. 21. Tip of cucumber root with young nematodes, *Heterodera radiculicola*, just entering. Enlarged.
(Massachusetts Experiment Station.)

in length—within the root, the female finally becoming club-shaped, but the male resuming its original slender form. The young, hatching from the eggs laid within the root, make their way into the soil, and thence into new roots.

Preventive and Remedial Measures.—Tools which have been used in soil infested by eel-worms should be thoroly washed or, better, sterilized before using them in other soil.

Among the most suggestive methods of treating infested green-houses is that used by Mr. W. F. Preston, of Dixon, Illinois. Having had serious trouble with nematodes on cucumber plants, he used the sterilization process about to be described, but, owing to the "solid bed," worms in the unsterilized soil below soon reinfested the treated soil. To prevent this, a cement floor was put in the bed about ten inches below the top, the wooden sides being retained. The nematodes did not reappear until the following summer, when the vines were old and ready to be removed, as was also the soil. They then gained entrance between the cement floor of the bed and the wooden side-walls. The soil could probably be wholly protected by making the sides as well as the floor of cement, sloping the floor from the center towards each side, and leaving holes along the sides, near the floor of the bed, for drainage.

Sterilization of the soil by steam is the most efficient measure of controlling the eel-worm, as well as many insect pests ordinarily introduced into the greenhouse with the soil, and various ways of accomplishing this have been devised by hothouse gardeners. Perhaps the earliest record of this soil treatment is that of Mr. W. N. Rudd,* of Chicago, who used it successfully in 1893. The most practical and economical method with which I am acquainted, is that of Mr. J. F. Ammann, of Edwardsville, Illinois. Into a sterilizing bin of rough boards, measuring two feet high, 10 feet wide, and 20 feet long, about a foot of soil is placed, and a heating apparatus of five "runs" of old perforated two-inch pipe is laid and connected with the steam supply. Another foot of soil is added, and potatoes are placed in the bin, one at each end and another in the center. The bin is then covered with a tarpaulin, and 80 pounds of steam are turned into the pipes for about an hour and a half, or until the potatoes are well cooked.

LETTUCE

The cultivation of lettuce, tho carried on thruout the year, is confined to hothouses during the cooler months. The hothouse product is far the most important, and it is to this that insect pests are the most troublesome. Cutworms, the lettuce plant-louse, and the cabbage-worm are usually abundant enough to do it much damage, and need the close attention of the lettuce grower.

THE VARIEGATED CUTWORM

Peridroma margaritosa Haw.

(*Peridroma saucia*, *Agrotis saucia*)

Young lettuce, cabbage, and other plants, are often cut off, or otherwise eaten, by some unseen insect, and later the leaves may be so badly eaten as to ruin them for market. In such cases if one searches near the plant, just beneath the surface of the soil, he is almost certain to find a grayish or dark fleshy cutworm.

The only cutworm I found feeding on lettuce and other vegetables in the greenhouses and out-of-doors in 1908 was the species named above. The egg (Fig. 22, *e*) from which it hatches is about one-fiftieth of an inch in diameter, dome-shaped, with vertical ribs. When first laid it is creamy white with a pearly luster, but it soon changes to a pinkish tint, and finally to lilac or darker. The parent moth may deposit 500 eggs, or even more, in masses of 60 and upwards (Fig. 22, *f*). The larva hatches in five or six days, and after eating the egg-shell from which it has emerged,

*Killing Grubs in Soil. American Florist (Chicago), Vol. IX, Sept. 28, 1893, p. 171.

begins feeding on the lettuce leaf. When full grown (Fig. 22, *b*, *c*, *d*) it is about an inch and a half long. It is usually dull, blackish brown, mottled with gray, some larvæ being paler and others darker. A characteristic marking is a row of four to six yellowish dots along the median line of the back. This cutworm feeds at

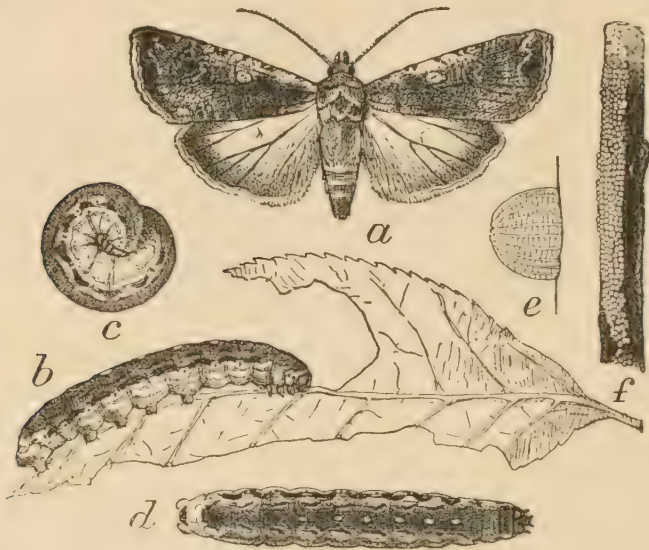


Fig. 22. Variegated Cutworm, *Peridroma margaritosa*: *a*, adult; *b*, larva, side view; *c*, same, curled up; *d*, dark-colored larva, seen from above; *e*, single egg; *f*, cluster of eggs on twig. All natural size except egg.

night, and hides during the day in the soil just beneath the surface, or under boards or rubbish near the plant. It remains a cutworm for 25 to 30 days, and then goes into the ground and pupates in an oval earthen cell, usually found just below the surface. Fifteen to nineteen days later it comes out as a moth (Fig. 22, *a*). The pupa is shining reddish brown, growing darker with age. It is about an inch long, slightly pointed at one end and rounded at the other. The moth measures about one and three quarters inches across the expanded wings. The fore wings are brownish, mottled with black or gray, the shades and markings varying considerably. The hind wings are nearly uniform grayish or pale brownish, with a darker border. Like the larva, the moth is nocturnal in habit, and the eggs are laid at night. The adult may live a week or more, but rarely lasts more than ten days. The complete life cycle in summer requires 45 to 54 days, but in winter, in greenhouses, the period is much longer. Out-of-doors there are two generations in a year, and in greenhouses probably four or more. According to various writers the winter may be passed outdoors in either the pupal, larval, or adult stage.

Natural Enemies.—A single tachinid fly (*Archytes aterrima* Desv.)* has been bred from this cutworm in Illinois, but three species of these flies and several hymenopterous parasites have been reported to infest it elsewhere. None of these, however, is of much importance in lessening its numbers.

Remedial Measures.—In the greenhouse, for such vegetables as lettuce, insecticides may best be used in the form of a poisoned bait. Successful experiments against cutworms were made by me in a Chicago greenhouse this year (1908) with both poisoned bran and poisoned lettuce leaves. In lettuce houses the latter will usually be the most convenient. If the soil is new, and especially if it is a sod soil, lettuce leaves should be laid on the beds and dry Paris green sprinkled lightly over them before the crop is planted. Or if the lettuce has already been planted, it should be pulled up if cutworms are abundant, and a row of lettuce leaves should be laid along each side or in the center of the bed, and then poisoned. Even tho there are but very few cutworms in the greenhouse, it is always best to repeat this process at the final gathering of each crop. It is but little trouble to lay fresh refuse leaves along the bed and sprinkle them with the poison.



Fig. 23. Trap lantern for adults of cutworm.

A lantern trap (Fig. 23) is also useful in the greenhouse. This consists of a tub with an inch or two of water in the bottom and a little kerosene to form a surface film, and a lantern is hung over the tub to be kept burning for several nights. The moths are at-

*Determined by C. A. Hart.

tracted by the light, and in flying around it drop into the tub and are killed by the oil.

Outdoor plants, such as cabbages, beets, and onions, may be protected by the use of poisoned bran mash, the formula for which is given on page 155. This should be placed in small piles, about a tablespoonful to a pile, at the bases of the plants. When a field which has been in grass is to be planted to vegetables, it is well to use the poisoned bran in spring, shortly before planting the crop.

Dusting or spraying plants with Paris green or arsenate of lead is effective against cutworms and safe for most vegetables, but not for lettuce.

It is often easier to pick, brush, or shake off cutworms than to destroy them by poison.

In agricultural practice, early fall-plowing is often helpful if done while cutworms are still actively feeding. Their food being thus destroyed, many will starve, and others will be too weak to survive the winter. On the other hand, if the plowing is delayed until the cutworms have pupated, little or no benefit will follow. Crop rotation may sometimes be useful, but as very few garden plants are unmolested by cutworms, it is not to be relied on. Nevertheless, if it can be avoided, the more succulent plants should not be grown in soil known to be infested by cutworms.

Clean culture is, of course, important. Weeds and rubbish afford excellent breeding places for cutworms as well as for many other insects.

THE LETTUCE PLANT-LOUSE

Macrosiphum lactucae Kalt.

(*Nectarophora lactucae*, *Siphonophora lactucae*, *Aphis lactucae*)

The lettuce-louse is probably to be found in every Illinois greenhouse where lettuce is grown. It often becomes very abundant, especially in the lettuce heads, and not only stunts the plants, but makes the product unsalable because it is impossible to free the heads thoroly from the lice. I have also found this louse on celery out-of-doors, but never sufficiently abundant to do injury.

Its life history is the same as that of most other plant-lice: that is, the viviparous female reproduces without the intervention of the male, and gives birth to living young. Each louse may produce 50 to 100 young, and because of this great reproductive capacity a greenhouse may be almost overrun before the presence of the insects has been noticed.

Natural Enemies.—Fortunately, this species, like most plant-lice, is subject to the attacks of many parasitic and predaceous insects which do much to control it. They are seldom capable of

holding it completely in check, however, and remedial measures must be resorted to.

Remedies.—Only remedies to be used in greenhouses need be mentioned, as this louse has not been found by us of economic importance elsewhere.

Fumigation is the only satisfactory remedy. The lice are usually within the heads, making it almost impossible to reach them with a spray; and at any rate the use of an effective spray would probably spoil the lettuce for the market. Tobacco or one of the tobacco extracts, or, better, hydrocyanic acid gas, may be used as a fumigant. The latter is the more effective, and will also destroy the white-fly and the aphids of the cucumber, which plant is usually grown in the same houses with lettuce. (See pages 156 and 159.)

THE IMPORTED CABBAGE-WORM

Pontia rapæ Linn.

(*Pieris rapæ*)

Occasionally the cabbage-worm becomes abundant and destructive to greenhouse lettuce, and I have seen beds which were planted the last part of August or the first part of September completely ruined by it. It has been already sufficiently discussed as one of the cabbage insects (pages 104-107).

Methods of Control.—As arsenicals can not be used on lettuce, it is hardly probable that the cabbage-worm in greenhouses can be successfully treated by any of the measures advised for its control out-of-doors (pages 106-107). If there are cabbage gardens near a greenhouse, it is not advisable to plant lettuce until the middle or last of September. If, in spite of precautions, a bed becomes badly infested, the plants should be thoroly sprayed with Paris green, and pulled up within two or three days, after which the bed may be replanted.

ONION

With the possible exception of the potato, the onion is the most important garden product of Illinois and its insect enemies are the most difficult to control. In 1899, 2,563 acres were used for the growing of onions in this state, and the acreage has enormously increased since then. There are but two onion pests which are of general economic interest, the onion-maggot and the onion thrips.

THE ONION-MAGGOT

Phorbia ceparum Meigen

(*Pegomyia cepetorum*, *P. ceparum*, *Anthomyia ceparum*)

Any one who has ever had anything to do with onion-growing is fully aware of the great damage done by the onion-maggot (Fig.

26). As soon as the plant begins to sprout, the work of the maggot begins, and it is at this time that much of the damage is done, altho it is not so evident then as later. Much of the trouble attributed to poor seed is really due to the maggot, which may attack and quickly kill the plants just as they appear above ground, or even sooner. The earlier the attack the greater the number of plants destroyed, since more will be eaten by the maggot.



Fig. 24. Onion-maggot, *Phorbia ceparum*, female and head of male. Length of body about three-sixteenths of an inch.

The adult (Fig. 24) of this maggot is very similar to the common house-fly in general appearance, except that it has a grayish thorax and is somewhat smaller. It is a near relative of the cabbage root-maggot, already described, and the two insects, as well as their work, are much alike. The winter may be passed in any one of its various stages excepting the egg. Hibernating adults, or adults maturing early in spring, deposit eggs deep in the cracks and crevices of the earth, near the young plants. The minute maggots hatching two to four days later, more or less according to the prevailing temperatures, make their way to the bulb and begin feeding on the roots and the underground parts of the plant. They burrow within the bulb, causing the inner parts to decay. An infested onion may appear sound, but by pressure the rotten parts and the maggots may be forced out. When full grown, some two or three weeks after hatching, the maggots change to brownish

oval puparia (Fig. 25) in the bulbs or in the earth not far from the onions in which they have been feeding. These puparia trans-

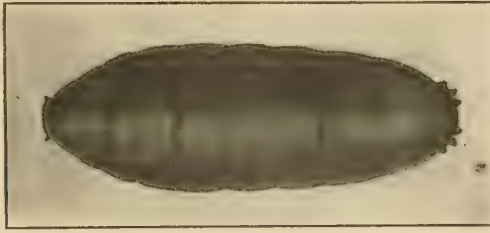


Fig. 25. Onion-maggot, *Phorbia ceparum*, puparium. Length about one-fourth inch.

form to adult flies in about two weeks, and the flies, in turn, deposit eggs for a second generation.

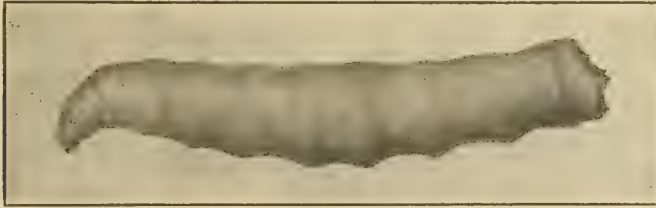


Fig. 26. Onion-maggot, *Phorbia ceparum*, larva, side view. Length of body about five-sixteenths of an inch.

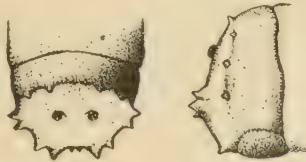


Fig. 27. Onion-maggot, *Phorbia ceparum*, tip of larva, top and side views. Greatly magnified.

Natural Enemies.—The onion-maggot has a few parasitic enemies, but they are seldom numerous enough to hold it in check, and have little economic value in Illinois. Chickens and other domestic fowls are fond of this insect, but on a large onion farm, it would be too difficult and expensive to keep enough of them to be of much assistance.

Methods of Control.—As this insect often lives over the winter as a maggot or as a puparium in the onion bulb, it is of great importance that the fields should be thoroly cleaned up in fall, no onions being allowed to remain there over winter.

As a rule, this pest is more abundant and destructive on comparatively sheltered areas than in open fields over which the winds

have full play. This fact should be borne in mind in locating onion beds.

The amount and kinds of manure used may have an important influence on the damage done by this insect. Prof. C. G. Hewitt, of the University of Manchester, England, has recently shown* that *Anthomyia radicum*, a European species very closely related to the onion-maggot, breeds freely in horse manure. It has often been noticed by entomologists and gardeners that fields which have been abundantly manured are worse infested than those where little manure has been used.†

It is much easier to keep these maggots from infesting onions than to kill them after their appearance. The three best repellents and preventives which have been recommended from time to time are hellebore, tobacco dust, and dry lime. The first two are discussed under remedies for the cabbage root-maggot, (pages 109 and 110) and on pages 154 and 155. Dry lime may be applied in the same manner as tobacco dust. These substances either repel the fly or prevent the maggot from reaching the plant even tho the eggs are deposited. They should be applied about the time the plants are sprouting or just as they appear above ground.

After plants have become infested it is often possible to kill the maggots before they enter the bulb by applying a contact insecticide. Carbolic acid emulsion and a decoction of hellebore (pages 153, 154) have given the best results. They should be applied as soon as the maggots are noticed, or at least before they enter the bulbs, otherwise it is impossible to reach them with any insecticide.

Old onions may be used as traps for the maggots by placing them along the edges of the field in small piles in early spring, before the onion seed has been planted. The flies will be attracted to these decaying onions, which should be destroyed after infestation, particular care being taken to do this before any of the maggots have become adults.

Mr. F. A. Sirrine‡ suggests the following hand method: "To get at the onion-maggot after the eggs have been laid, carefully lift all the infested onions and destroy the maggots by crushing or by dipping in kerosene. If this is done early in the season, when their work is first noticed, it will be no more of a task than the process of first weeding."

*On the Life-history of the Root Maggot, *Anthomyia radicum*, Meigen. Jour. Econom. Biol., Vol. II, Pt. 2 (Aug. 31, 1907), p. 57; and On the Bionomics of certain Calyptrate Muscidæ and their Economic Significance, with especial Reference to Flies inhabiting Houses. Ibid, Pt. 3 (Dec. 11, 1907), pp. 86-87.

†For tests with "blood and bone" see page III.

‡Maggots and Smut in Onions. Rural New Yorker, May 12, 1900, Vol. 59, p. 334.

The use of commercial fertilizers, to force the plants rapidly at first, will greatly lessen the amount of injury by the maggot.

THE ONION THRIPS

Thrips tabaci Lind.

In July or August one sometimes sees whitened onion plants in numbers sufficient to give the entire field a hoary look. This "white blast," as it is often called, is due to a tiny winged insect, the thrips of the onion, sometimes incorrectly called the "onion-louse," which often appears in great numbers, feeding first at the axils of the leaves. It does not actually eat the leaves, for its

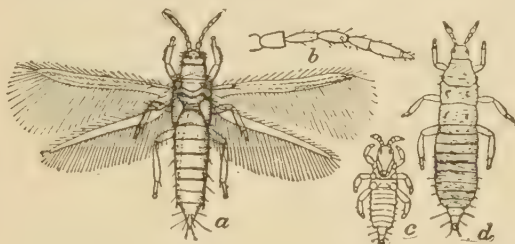


Fig. 28. Onion Thrips, *Thrips tabaci*: a, adult; b, antenna of same; c, young larva; d, full-grown larva. All highly magnified.

mouth parts, which form an inverted cone projecting from the under side of the head, are not of the true biting type. It pierces the epidermis of the leaf, and by moving the tip of the cone backward and forward it makes an opening, thru which it sucks the juices of the plant. Since this thrips is a general feeder, attacking many cultivated plants as well as weeds, it is of great economic importance, not only to the truck gardener but to the florist also. It is often injurious to cabbage and to cucumber plants in green-houses.

Its eggs are deposited just within the leaf tissue. The young (Fig. 28, c) are very minute at hatching, elongate, and pale yellowish. The adults (Fig. 28, a) closely resemble the young in shape, but differ by their darker color, and usually by the possession of wings. There are several generations a year, the number varying according to the season. The winter is passed in either the larval or the adult stage.

Natural Checks.—The insect enemies of this thrips are of no importance, but the character of the weather has a noticeable influence on its abundance, wet weather being decidedly to its disadvantage.

Remedial Measures.—The standard insecticides for thrips are kerosene emulsion and whale-oil soap. Spraying must begin at the first appearance of the insects, and must be repeated in a week or ten days. The most effective indoor remedies are thoro and fre-

quent fumigation with tobacco and tobacco extracts, or with hydrocyanic acid gas.

Clean culture is very important, since thrips hibernate on weeds and grasses along the edge of the onion fields. By plowing up all weedy and grassy land late in fall, after the thrips have left the onions, or by thoroly burning over such land during the winter, the number of thrips can be greatly diminished. Entire communities should practice these farming methods, for otherwise fields properly cared for may become reinfested from those neglected.

GARDEN PEAS

Garden peas are grown to a considerable extent by many of the market gardeners, and one insect pest, the pea-louse, has been found to do great injury to this crop in Illinois.

THE PEA-LOUSE

Macrosiphum pisi Kalt.

(*Nectarophora destructor*, *Siphonophora pisi*, *Aphis pisi*)

This plant-louse (Fig. 29) is common in all parts of the United States, and is a pest of some importance in Europe, its original



Fig. 29. Pea-louse, *Macrosiphum pisi*, on stems of red clover.
Natural size.

home. Its life history is not unlike that of plant-lice already described. The adult is about the size of a pin-head, or a little larger.



Fig. 30. Pea-louse, *Macrosiphum pisi*, winged viviparous female.
Greatly magnified.

pale green, and soft. It may be winged (Fig. 30) or wingless (Fig. 31). The winter is passed either in the egg or the adult stage, and usually on clover, from which it migrates to the pea in spring, sometimes multiplying enormously on this crop.



Fig 31. Pea-louse, *Macrosiphum pisi*, wingless viviparous female.
Greatly magnified.

Natural Enemies.—Many parasitic and predaceous insects prey on the pea-louse and materially aid in checking its rapid multiplication, the parasites not infrequently becoming numerous enough to control it completely. (Fig. 32.)



Fig. 32. Pea-louse, *Macrosiphum pisi*, empty skin after the emergence of a winged parasite. Greatly magnified.

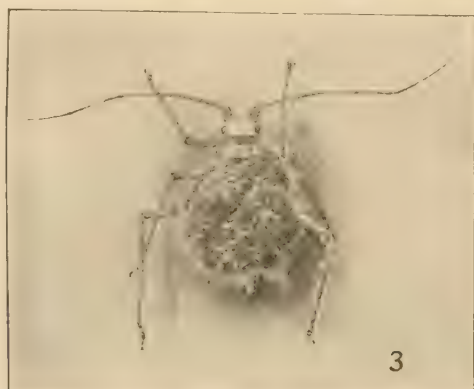


Fig. 33. Pea-louse, *Macrosiphum pisi*, attacked by fungus. Greatly magnified.

Remedial Measures.—Sprays of kerosene emulsion or whale-oil soap solution are probably the best remedies known. They should be applied at the first appearance of the lice, and continued as needed.

The brush and cultivator method is also much used. With this in view the peas must be planted in rows at least two feet apart. As soon as the lice infest the vines, and at intervals subsequently, they are brushed from the vines and covered by a cultivator before they can get back. Brooms made of fresh-cut pine branches have been suggested for brushing the lice from the vines.

POTATO

The potato is the most important vegetable grown in Illinois, both in acreage and value of the crop. Tho it is attacked by a

number of insect pests, none are of much economic importance in this state except the Colorado potato-beetle, the wireworms, the flea-beetles, and the potato plant-louse. The stalk-borer (*Papaipema nitela*) is also occasionally injurious to this crop. For a discussion of this insect see pages 147-148.

THE COLORADO POTATO-BEETLE

Leptinotarsa 10-lineata Say

(*Doryphora 10-lineata*)

This common and injurious species has doubtless caused greater damage to potatoes in Illinois than any other insect, and it is found on the vines in destructive numbers every year. It is a western species, its original habitat being the Rocky Mountain region. Its native food consisted of wild plants closely related to the potato, and when potato-culture reached its native prairies it promptly availed itself of the increased food supply thus afforded. It began its migration eastward, by way of the potato fields, about the year 1860, reaching Illinois some fifteen years later. Except in the Pacific coast region, it is now found generally distributed thruout the United States and Canada, wherever the potato is grown.



Fig. 34. Potato-beetle, *Leptinotarsa 10-lineata*: a, a, eggs; b, larvæ, young and full-grown; c, pupa; d, adults; e, wing-cover of adult; f, hind leg of adult. Natural size except c and f.

The yellow and black striped beetle (Fig. 34, d, d) passes the winter in the ground, and makes its appearance early in spring. It feeds at first on the young potato plants if these are at once available, or, if not, on some one of its wild food-plants. The sexes soon

mate, and the clusters of bright yellowish-orange eggs (Fig. 34, *a, a*) are deposited on the under side of the leaves. Each cluster may contain from 25 to 75 eggs, or even more, and individual beetles have been known to lay as many as 3,000 eggs under certain artificial conditions. The average number, however, is about 450.* The fleshy, grub-like larvæ (Fig. 34, *b, b, b*) hatch in four to seven days and at once begin to eat the potato leaves. They are dark red when hatched, but gradually become paler as they grow, with two rows of blackish spots along each side of the body. When two or three weeks old they go into the ground for pupation, emerging as beetles one or two weeks later. These beetles may feed and then go into hibernation, or eggs may be deposited for another generation. The number of generations is still in dispute, but there is probably but one as a rule, only a few of the beetles first to emerge laying eggs for a second generation the same year.

Natural Enemies.—Insect enemies of the potato-beetle are not uncommon, but it is doubtful if in Illinois they ever play any considerable rôle in reducing its numbers. Its commonest parasite in the vicinity of Chicago was a Tachina fly—*Phorocera rufilabris* V. d. W.† The white eggs of this fly were common on the backs of both beetles and larvæ—on the thoracic plate of the adult, and between the thoracic segments of the larva. The maggots hatching from these eggs enter the bodies of the beetles or the larvæ, soon killing them. Many predaceous enemies are known, including soldier-bugs, robber-flies, spiders, ground-beetles, ladybirds, tiger-beetles, rove-beetles, and some native birds and the domestic fowls.

Methods of Control.—The two standard remedies for injuries by this pest are Paris green and arsenate of lead. In Illinois, dry Paris green, with or without lime or flour, is used by nearly all potato growers. It has the advantage of being easy to prepare and apply, but there are offsetting disadvantages which make it less desirable than Paris green in water. It is less adhesive than the fluid spray, and hence must be applied more frequently, and more labor is required. The dry poison is very injurious when breathed into the lungs by the person applying it. Bordeaux mixture should always be added to Paris green when it is applied in water—as also to the arsenate of lead—for this compound spray is more effective against flea-beetles, and is a remedy for blight. Furthermore, the lime in the Bordeaux unites with the Paris green, thus increasing its adhesiveness, and it changes the soluble arsenic to insoluble, thus preventing the burning of the foliage which often follows when Paris green is used alone. The method of preparation is given on pages

*Further Biological Notes on the Colorado Potato-beetle, *Leptinotarsa decemlineata* (Say), by Alec. Arsène Girault. Annals Ent. Soc. America, Vol. I, No. 2 (June, 1908), p. 158. Columbus, Ohio.

†Determined by C. A. Hart.

151-153. The potato patch, and indeed the entire farm, should be kept free from weeds of the nightshade family, for the potato-beetle can breed on these.

WIREWORMS

Limoni~~us~~ confusus Lec.

But one kind of wireworm has been found by us common enough in Cook county to require special mention, but this single species is very injurious there to potatoes (Fig. 35, 36), radishes, onions, turnips, tomatoes, cabbage, corn, and horseradish. It burrows into or



Fig. 35. Potatoes showing injury by wireworms, *Limoni~~us~~ confusus*.

devours the roots and tubers of these vegetables, thus often completely ruining the crop. With the exception of the onion, tomatoes, cabbage, and corn, the plants above mentioned give no evidence above ground of the presence of wireworms, their attacks seldom weakening the plant, but merely disfiguring the marketable part.

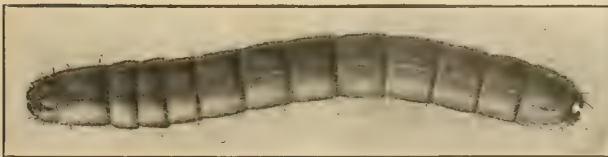


Fig. 36. Wireworm, *Limoni~~us~~ confusus*, larva.
Length about three-fourths inch.



Fig. 37. Tip of larva,
seen from above.
Greatly magnified.

Remedial Measures.—Three methods of control are practiced: rotation of crops, fall plowing, and poisoned baits. Cropping for two years with some vegetable which is virtually immune, such as beans, peas, spinach, cucumber, melon, rhubarb, lettuce, or pepper, should rid the soil of wireworms.*



Fig. 38. Wireworm, *Limonius confusus*, adult beetle. Length about three-sixteenths inch.

Late summer or fall plowing is frequently resorted to in order to destroy the pupæ and beetles. The land should be cultivated thoroughly several times in the fall.

Trapping the adults by poisoned baits is a method sometimes used in the eastern states. Sliced potatoes, wads of green clover, or corn-meal dough, poisoned with Paris green, have been found effective.† These baits should be placed under boards in various parts of the field, and renewed once or twice a week during the spring and early summer.

*This list is given on the authority of those who have reported these plants to be practically uninjured by wireworms, even when the latter are present in the soil.

†Our own experiments the past year with poisoned baits for this insect were not sufficiently effective to pay for the labor and materials.

THE POTATO FLEA-BEETLE

Epitrix cucumeris Harr.(*Crepiododera cucumeris* Harr.)

Potato leaves are often riddled with small holes as if they had been the target for a discharge of shot. Such injury is the work of flea-beetles. The life history and habits of the potato flea-beetle



Fig. 39. Potato Flea-beetle, *Epitrix cucumeris*, adult. Enlarged as indicated.

(Fig. 39) are essentially the same as those of the cabbage flea-beetle, which is discussed on pages 113-114.

Remedies.—The best remedy is spraying with Paris green, or arsenate of lead, and Bordeaux mixture, as recommended for the potato-beetle (page 142). Potatoes may be thus protected against the potato-beetle, the flea-beetle, and the blight. Other remedies applicable to this pest may be found on page 114.

THE POTATO PLANT-LOUSE

Macrosiphum solanifolii Ashm.(*Nectarophora solanifolii*, *Siphonophora solanifolii*)

The potato plant-louse is often a very troublesome species, densely infesting the tops of the plants and soon stunting or even killing them. It is so much like the notorious and destructive pea-louse that the two species can not be distinguished without a closer examination than the ordinary observer is likely to make. Altho commonly pale greenish, there is a red variety of this species which, during the summer, is often as abundant as the commoner green form. The life history and natural enemies of this aphid are similar to those of other plant-lice already described.

Remedial Measures.—The only available remedies are those suggested for other plant-lice; namely, kerosene emulsion and soap solutions (page 153).

Clean culture seems to be of much importance, inasmuch as the eggs are deposited in fall on shepherd's-purse and possibly on various other weeds.*

Fall plowing and burning over grassy and weedy areas in the neighborhood of potato fields are certainly to be recommended; and Miss Patch further commends, as a precaution, the practice of burning old potato stalks, since belated specimens of the plant-lice may possibly remain on them under certain conditions.

SPINACH

Spinach is often attacked in fall by a plant-louse which sometimes destroys entire fields.

THE OMNIVOROUS PLANT-LOUSE

Myzus persica Sulz.

(*Rhopalosiphum dianthi*, *Aphis dianthi*)

In the fall of 1908 my attention was attracted to the great abundance of a plant-louse infesting spinach on many truck-farms near Chicago. This louse may feed on almost any plant, as the common name above given implies. Among the vegetables which it sometimes injures, weakening the plants and causing a curling of the leaves, are turnip, radish, celery, cabbage, and cauliflower. It is impracticable to wash off these green lice after they become abundant, and the presence of thousands of them on the spinach renders it unsalable.

Remedies.—The only practicable remedy is thoro spraying with a contact insecticide which will not give a permanent odor or taste to the leaves. The standard tobacco or nicotine extracts (page 154) answer the purpose. It is very important that spinach should be closely watched, and that the plants be sprayed at the first appearance of the lice. The treatment should be repeated at intervals as may be necessary.

TOMATO

Altho not extensively grown in the truck gardens of Cook county the tomato is of much importance in other parts of the state, particularly as supplied to canneries. A stalk-borer (*Papaipema nitela*) is the principal insect enemy of the crop in Cook county, and is no doubt the cause of more damage than is commonly charged to it. To the casual observer there is no indication of the presence of this insect when the plants wilt and die from its attack, and as a rule the gardener is at a loss to find the cause, the characteristic round hole in the stalk being easily overlooked. Occasionally the Colorado

*According to Miss Edith M. Patch. See "The Potato Plant Louse." Bull. Maine Agr. Exper. Station, No. 147 (Nov., 1907), pp. 247-248. Orono, Me.

potato-beetle, treated on pages 141-143, damages tomatoes soon after transplanting to the field.

THE STALK-BORER

Papaipema nitela Guen.

(*Hydræcia nitela*, *Gortyna nitela*)

This borer, or "heart worm," as it is often called by corn growers, was found destructive to tomato and corn, and occasionally to potato, in a number of restricted areas during the past year. Other vegetables known to be injured by it are rhubarb, spinach, cauliflower, eggplant, and pepper.

The presence of this caterpillar in the tomato plant is indicated by the wilting or death and final breaking down of the top, and by the presence of a round hole in the side of the stalk, from which a

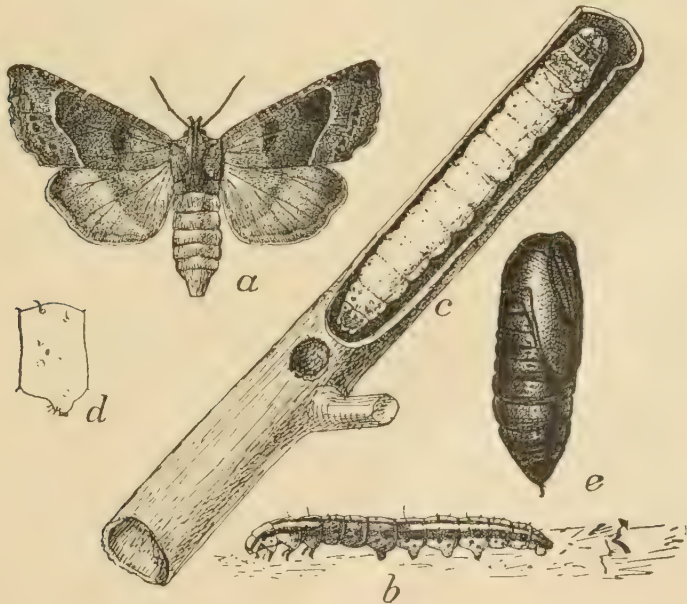


Fig. 40. Stalk-borer, *Papaipema nitela*: *a*, adult; *b*, half-grown larva; *c*, mature larva in burrow; *d*, side of one of its segments; *e*, pupa. Slightly enlarged.

brownish excrement is oozing. Upon careful examination of plants so injured a peculiarly striped larva (Fig 40, *b*) will usually be found in the stalk. The following description is quoted from Professor Forbes.*

The larva may be readily recognized "by the peculiar break in the striping of the body at the middle * * * [Fig. 40, *b*] giving it an appearance as if it had been pinched or injured there. It is

*Twenty-third Rep. State Ent. Ill., pp. 44, 45.

about an inch long when full grown. The general color varies from purplish brown to whitish brown, according to age, and it is marked with five white stripes, one running down the middle of the back, and two on each side * * *. The stripes nearly vanish as the larva matures [Fig. 40, *c*]. The head and top of the neck, and the leathery anal shield at the opposite end of the body are light reddish yellow with a black stripe on each side."

The young caterpillar first feeds within the stems of grasses or weeds, but as it becomes larger it is compelled to seek thicker-stemmed plants, and it is at this time that it begins to infest garden vegetables. In northern Illinois, in 1908, half-grown larvæ were found in tomato stalks the middle of June, when fully half the plants in the field had been killed by them. The larva usually enters the stem near the base and burrows upwards. When full grown it changes into a reddish brown pupa (Fig. 40, *c*) within the stalk, usually below the original entrance-hole, and later the grayish moth (Fig. 40, *a*) emerges. According to Prof. F. L. Washburn * the eggs of this moth are deposited in masses on the stem of the plant near its base. It is supposed that they are laid in grass lands in fall, and that they hatch the same season or the following spring.

Economic Procedure.—After plants have become infested, no remedy can be used to save those individual plants, and they should be pulled up and burned immediately to prevent the larvæ from entering other plants, and also to decrease the number of the borers for the next year.

In spring, vegetation around tomato, potato, and corn fields should be watched, and if it is wilting or dying it should be examined to learn if this borer is present, in which case the weeds should be cut and destroyed without delay.

Late fall-plowing of infested fields is advised in order to bury the eggs, which, as already said, are supposed to be laid in grass or weedy land in fall, and all weeds, not only in the fields but along the roadsides adjoining them, should be destroyed at this time.

PREPARATION OF INSECTICIDES FOR USE AGAINST INSECTS INJURIOUS TO GARDEN AND HOTHOUSE VEGETABLES

From the economic point of view insects are divisible into two classes; those which chew and swallow the tissues of the plant, and those which suck their juices. Insects of the first class—cabbage-worms, potato-beetles, and cutworms, for example—can usually be destroyed by one of the so-called stomach poisons listed on page 149; but those of the second class—plant-lice, thrips, the white-fly,

*Preliminary Report upon Work with the Stalk Borers in Minnesota. 12th Rep. State Ent. Minn., p. 151. Dec., 1908.

etc.—are unharmed by such insecticides because they take their food from the interior of the plant, and so a contact insecticide must be used.

The classification in the following synoptical list of insecticides is based on their most obvious distinctions, and the subsequent treatment corresponds to the order of the list.

Dust or Liquid Sprays.

Page

Stomach poisons for biting insects.

Paris green, dry, with or without an adulterant.....149

Paris green, liquid spray 150

Arsenate of lead 150

Resin-lime mixture, with a poison 150

Bordeaux mixture, with a poison 151

Contact insecticides—for sucking insects.

Kerosene emulsion 153

Whale-oil soap solution 153

Carbolic acid emulsion 153

Hellebore decoction 154

Insect powder (pyrethum or buhach) 154

Tobacco decoction and nicotine preparations 154

Lye-sulphur wash 155

Poisoned Baits—for biting insects.

Poisoned bran mash 155

Poisoned lettuce or clover leaves 155

Repellents—for any insects.

Carbolic acid and lime 155

Tobacco dust 155

Lime, dry 156

Bordeaux mixture 152

Fumigants—for any insects.

Hydrocyanic acid gas 156

Carbon bisulfid 158

Sulphur 159

Tobacco stems 159

Nicotine preparations 159

PARIS GREEN—DRY

Unmixed Paris green may be sprinkled upon plants, but the danger of burning the leaves is lessened by adulterating it with flour.

land-plaster, or air-slaked lime in the proportion of one pound of the poison to twenty-five pounds of flour or to fifty pounds of land-plaster or lime.

Apply thoroly and evenly with a hand "dust-sprayer" early in the morning, when the dew is on the plants.

PARIS GREEN—LIQUID SPRAY

Formula

Paris green	1 pound
Unslaked lime	1½ pounds
Water	150 gallons

Slake the lime and add the Paris green, thoroly mixing before adding the water. The mixture must be kept well stirred while it is being sprayed, and most spray-pumps have an attachment for this purpose. The liquid spray is safer and more efficient than either of the dry mixtures previously mentioned.

ARSENATE OF LEAD

Arsenate of lead can be made by properly combining lead acetate and arsenate of soda, but it is difficult to make a good grade of it, and unless large quantities are needed it is best to purchase standard brands, which are ready for use when dissolved in water.

The price of arsenate of lead is less than that of Paris green, but as one must use two to three times as much of it to secure a desired result, it is slightly more expensive as an insecticide than Paris green. This fact is offset, however, by the following advantages which arsenate of lead has over all other arsenicals: it is much more adhesive, remaining on the foliage for a period during which two or three sprayings with Paris green would be necessary; it remains in suspension better; it shows on the foliage; and it is harmless to vegetation, this last fact being of special advantage when the more tender plants are sprayed.

Care should be taken to obtain a good grade, for there are many worthless brands on the market. Usually a good grade can be obtained from any reliable wholesale druggist. As the strengths of the various brands differ, the gardener should follow the directions accompanying the arsenate he is to use.

RESIN-LIME MIXTURE

The resin-lime mixture serves as a stock solution to which poisons may be added. It is valuable chiefly because of its adhesive properties, being for this reason well suited to smooth leaves, such as those of the cabbage. It has the disadvantage, however, that considerable time is necessary for its preparation, and that it is especially liable to clog the spray-nozzle. It is prepared as follows.

Stock Solution

Pulverized resin	5 pounds
Concentrated lye	1 pound
Fish oil, or any animal oil except tallow ..	1 pint
Water	5 gallons

Place the resin, oil, and a gallon of hot water in an iron kettle and heat until the resin is softened, after which the lye should be added to the heated mixture and the whole thoroly stirred. Then add the remaining four gallons of water and boil for about two hours, or until it will unite with cold water and make a *clear*, amber-colored liquid. If there is less than five gallons of the preparation, add water enough to make that quantity. This stock solution will keep indefinitely, and the quantity needed for the whole season may be made up at one time.

Preparation for Use

Stock solution	1 gallon
Water	16 gallons
Milk of lime*	3 gallons
Paris green	$\frac{1}{4}$ pound

First add the water to the stock solution, mixing thoroly; then add the milk of lime; and, finally, add the Paris green, previously stirred up with water to form a thin paste. The whole mixture must then be thoroly stirred. This preparation should be made up as needed, for if allowed to stand any considerable time it will settle, and will also gum up the pump valves and the nozzles.

BORDEAUX MIXTURE AND PARIS GREEN

Bordeaux mixture is primarily a fungicide: but it is also useful as a repellent against some insects, and with Paris green or arsenate of lead it makes an excellent combination spray to be used when both fungi and leaf-eating insects are to be dealt with on the same crop.

Various strengths of the Bordeaux are used by the vegetable gardener according to the plants to be sprayed. Those in commonest use are often conveniently designated as 4-4-50, and 6-6-50. The significance of the figures is evident from the following 4-4-50 formula:

Copper sulphate	4 pounds
Quicklime	4 pounds
Water	50 gallons

For such plants as asparagus, tomatoes, and melons, the 4-4-50 strength is used; and for the potato and related plants, the 6-6-50.

*Milk of lime is made by slaking stone lime and adding sufficient water to make a thin whitewash.

To make the Bordeaux mixture, dissolve the copper sulphate in about 20 gallons of water—best done by placing the sulphate, or bluestone, as it is often called, in a gunny sack or other stout cloth bag and suspending it in the water. It will dissolve in a day or so, and if covered to prevent evaporation it will keep indefinitely. If less than 50 gallons of the Bordeaux mixture is needed, or if the solution is wanted immediately, the bluestone may be readily dissolved in hot water.† In another vessel slake the lime, adding the water slowly, to obtain a smooth, creamy liquid, using barely enough water to cover the lime after it has settled. In this condition, if evaporation is prevented, it will, like the copper-sulphate solution, keep indefinitely.

When ready to spray add enough water to each stock solution, separately, to make 25 gallons, stir each thoroly, and then mix the two together. This may be done by having the barrels containing the two solutions on a high support, with plugs near the bottom so that both solutions can be run into a third vessel below, the operator stirring the fluids as they unite. Or, if such an apparatus is not obtainable, the mixture may be made by pouring the two fluids together from buckets (Fig. 41).



Fig. 41. Method of preparing Bordeaux mixture by hand.
(Missouri Experiment Station.)

For the combined fungicide and insecticide, add five or six ounces of Paris green, previously made into a paste with water, to fifty gal-

†Copper sulphate, either dry or in solution, corrodes iron, and a wooden, earthen, brass, or copper vessel should be used.

lons of Bordeaux mixture, and thoroly stir. If arsenate of lead is used in place of the Paris green, about four or five times as much will be required.

Altho the separate solutions of the copper sulphate and of the lime are stable, they are not so when combined, and therefore only the quantity to be used at the time should be made up.

KEROSENE EMULSION

Stock Solution (66 percent kerosene)

Soap*		1/2 pound
Kerosene		2 gallons
Water		1 gallon

If hard soap is used, cut it into fine shavings and dissolve in boiling water, after which remove from the fire and immediately add the kerosene and thoroly mix. This may be done most easily by churning for about ten minutes with a force-pump, the nozzle being turned back into the liquid; or, in the absence of a pump, the liquid may be turned from one bucket to another for fully ten minutes, holding the bucket high so as to give force to the falling liquid. When thoroly emulsified it will have the consistency of thick cream, and the oil will not separate out. There is great danger of injuring the plants if the mixture is not well and thoroly made.

For spraying vegetation the stock solution should be diluted to the desired strength. For a five percent emulsion add 37 gallons of water to 39 gallons of the stock solution; for a 10 percent emulsion add 17 gallons of water to the same; and for fifteen percent emulsion add 10½ gallons.

It is desirable to use soft water both for the stock and as a diluent, but if this is not obtainable the water should be softened by adding lye or sal-soda.

The emulsion should be applied to plants with a spray-pump, and in a fine mistlike spray. For most insects a ten percent emulsion is strong enough.

WHALE-OIL SOAP SOLUTION

Whale-oil soap is an effective insecticide for plant-lice and other soft-bodied insects. For use, dissolve one pound of the soap in six to eight gallons of hot water.

CARBOLIC ACID EMULSION

Carbolic acid emulsion is a contact insecticide, and also acts as a repellent, being chiefly used for the treatment of root-infesting insects.

*Either hard or soft soap may be used. Whale-oil soap and "Tak-a-nap" soap have given excellent results.

Stock Solution

Hard soap (preferably "Ivory" or "Tak-a-nap")	1 pound
Soft water	1 gallon
Crude carbolic acid	1 pint

Dissolve finely shaved soap in boiling water, add the carbolic acid, and churn as for kerosene emulsion. For use, one part of the stock solution is diluted with thirty to forty parts of water.

HELLEBORE DECOCTION

For use against root-maggots, this decoction is prepared by steeping two ounces of white hellebore in one gallon of hot water for 30 minutes. For insects infesting the foliage, one ounce of hellebore to two gallons of water is sufficient. Hellebore very soon loses its insecticidal properties by exposure to the air, and care should be taken to obtain only such as is known to be fresh.

INSECT POWDER (PYRETHRUM, OR BUHACH)

Pyrethrum, or insect powder, as this insecticide is commonly called, is of special value for killing certain kinds of insects, and it has the advantage of being harmless to human beings and the higher animals. On the other hand, its expense prohibits its use on a commercial scale, and it quickly loses its virtue when exposed to the air. If used in a dry form it should be mixed with twice its weight of common flour, and kept in a tightly closed vessel for 24 hours before using. It may be applied with a dust sprayer or some sifting apparatus. A decoction of pyrethrum may be made by mixing one ounce of the powder with enough water to form a thin paste and allowing it to stand several hours, after which sufficient water should be added to make two gallons. This is less effective than the dry powder.

In purchasing pyrethrum, only hermetically sealed cans of it are safe, for the reason already given, but if they can not be obtained care must be taken to buy only an absolutely fresh article.

TOBACCO DECOCTION AND NICOTINE PREPARATIONS

Tobacco decoction, altho not so effective as some of the above-mentioned contact insecticides, is still used by many for killing soft-bodied insects, such as plant-lice. It is prepared by steeping tobacco stems in hot water at the rate of one pound to two to three gallons.

More reliable than the above are various commercial preparations which likewise have nicotine as their active principle. (See page 159.)

LYE-SULPHUR WASH

This contact spray is said to have particular value against the red spider. It is prepared by mixing five pounds of flowers of sulphur with cold water and then adding to this sulphur paste two and a half pounds of pulverized caustic soda. Water is added from time to time, to prevent burning, until a concentrated solution of five gallons is obtained. One gallon of this stock solution is sufficient for 25 gallons of spray.

POISONED BRAN MASH

Bran	16 pounds
Paris green	1 pound

Slightly dampen the bran and add the Paris green, mixing until every particle of the bran bears some of the poison. The bran should be barely wet enough to make the powder adhere to it, as experiments in greenhouses strongly indicate that a soggy mash is not freely eaten by cutworms. A little salt in the water used is said to give the mixture additional relish.

POISONED LETTUCE OR CLOVER LEAVES

Small lots of lettuce or clover are poisoned with Paris green, either dry or suspended in water, and the poisoned vegetation is then cut or mowed and scattered over the infested tract (see page 131). This and the poisoned bran mash seem to be about equally effective.

CARBOLIC ACID AND LIME

A coating of the soil at the base of the plants with carbolic acid and lime has been recommended by Dr. John B. Smith * as "the most effective material tested" in his experiments against the onion-maggot in New Jersey.† To make the mixture, slake three pints of lump lime in a gallon of water, and add one tablespoonful of crude carbolic acid. When applied properly along the rows with a sprinkling-can or spray-nozzle, a thin crust will form on the ground around the plants, which is said to serve the same purpose as the tarred felt-paper protectors described on page 110.

TOBACCO DUST

Tobacco dust has been recommended as a useful repellent, particularly against such insects as root-maggots and cucumber-beetles. It has the further advantage of serving as a contact insecticide and

*The Cabbage and Onion Maggots. Bull. N. J. Agr. Exper. Station, No. 200 (Feb. 12, 1907), pp. 16-19.

†For reference to our own experience with it see page 110.

as an excellent fertilizer. Indeed, it is said that its value as a fertilizer alone is sufficient to cover its cost.

For leaf-eating insects it is dusted on the leaves early in the morning, while the dew is on. For root-feeding insects it is sprinkled along the rows at the base of the plants, preferably when the soil is moist.

DRY LIME

Fresh air-slaked lime or quicklime when used as a repellent for root-maggots is sprinkled along the rows close about the plants, and acts similarly to the carbolized-lime application. As some insects of economic importance are attracted to manures, the latter should be sprinkled over with lime where there is danger of infestation by insect pests.

Dry lime, especially when fresh, is strongly caustic, and is therefore valuable as a contact insecticide for slugs, plant-lice, and soft-bodied insects generally.

HYDROCYANIC ACID GAS

Hydrocyanic acid gas is doubtless the most powerful and effective fumigant known. Indeed, many are afraid to handle the deadly gas; but it can be used with perfect safety if proper care be taken.

It is impossible to give a set formula for its use, owing to differences in the structure of greenhouses. In those of average tightness I have used it on cucumber plants, without injury to them, at a strength of 1 ounce of potassium cyanide to 3,000 cubic feet of space—fumigating in the evening, and keeping the house closed over night.

The materials necessary for fumigation with hydrocyanic acid gas are potassium cyanide (98 to 99 percent pure), commercial sulphuric acid, and water; and the requisite utensils are half-gallon or gallon jars—stone, earthen, or granite—and a supply of ordinary small paper bags.

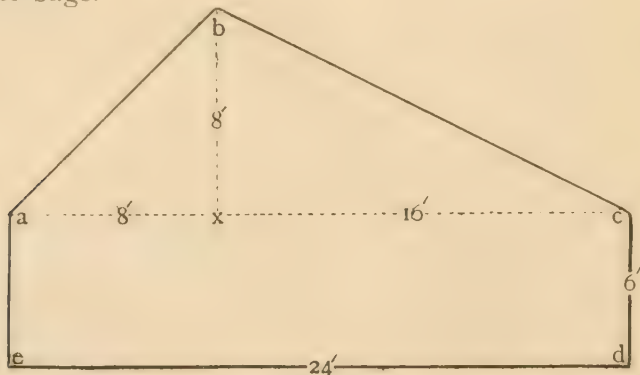


Fig. 42. Diagram illustrating determination of cubic contents of greenhouse.

The number of cubic feet in the house should first be accurately calculated. The method of doing this may be illustrated by a simple computation based on the dimensions given in the accompanying figure, the understanding being that the length of the greenhouse is 100 feet. (Fig. 42.) The cubic contents of the rectangular section of the house, $a c d e$, equals $24 \times 6 \times 100 = 14,400$ cubic feet; that of the triangular section $a b x$, equals $8 \times 8 \times 100 \div 2 = 3,200$ cubic feet; and that of the other triangular section, $b c x$, equals $8 \times 16 \times 100 \div 2 = 6,400$ cubic feet. The cubic contents of this house are, therefore, $14,400 + 3,200 + 6,400 = 24,000$ cubic feet. Assuming this house to be of no more than the average tightness, we may safely use potassium cyanide at the rate of one ounce to every 3,000 cubic feet of space, and 24,000 divided by 3,000 gives 8 as the number of ounces required in this illustrative case.

The next procedure is to prepare the materials for use and to place the jars in the house. For every ounce of the potassium cyanide used, two ounces of sulphuric acid and four ounces of water are required. Two ounces of the cyanide is about the right quantity for each jar, therefore, for a house of the above dimensions, four jars should be placed at equal intervals along the aisles, and the eight ounces of cyanide divided into four equal parts, and each part put into one of the paper bags. These are used not only for convenience in handling the cyanide when placing it in the jars, but also because they slightly delay the action of the sulphuric acid upon it, thus giving the fumigator ample time to leave the house before the reaction occurs. The jars being in place and the cyanide properly weighed and bagged, the next step is to close all the ventilators in order to prevent any avoidable escape of gas. The water—four liquid ounces to every avoirdupois ounce of cyanide—is then placed in each jar, the sulphuric acid—half as much as the water—is added, and as soon after as possible the bags of cyanide should be put into the jars and the house vacated immediately. Doors should be locked and labels posted indicating the danger. No one should enter the house until it has been thoroly aired by opening the side doors, and, if convenient, the ventilators also. It is best to fumigate in the evening, keeping the house closed till morning. I have never found a greenhouse so tight that the fumes would remain in it in dangerous quantities all night; nevertheless, it is safest to air the house well before entering.

Precautions and Miscellaneous Directions.—As cyanide of potassium is a powerful poison it should be handled as little as possible. It should be kept in tightly closed cans or jars, plainly labeled, where it will be inaccessible to persons not acquainted with its poisonous properties. Use only a grade 98 to 99 percent pure. It may be obtained in either granulated or lump form, the former being the most convenient for use in fumigation.

Sulphuric acid should not come in contact with the hands or with the clothes, as it will severely burn the flesh and ruin the clothes. It should not be placed in metal receptacles, as it will soon eat them thru.

Fumigate in the cooler parts of the day, and avoid, if possible, a temperature above 60° or 65° F., since at a higher temperature the plants are more liable to be injured.

The foliage of plants to be fumigated should be perfectly dry, otherwise it will absorb the gas and be burned.

The best-shaped jar, when using two ounces of cyanide to a jar is one four or five inches in diameter and about nine inches high. If more cyanide is to be used in each receptacle larger jars must be used.

Always put the water into the jars first, adding the acid later. Never pour water into the undiluted acid.

After placing the sulphuric acid in the jars the bags of cyanide should be put in as soon as possible, for any delay will interfere with the proper reaction of the chemicals owing to the fact that the acid acts most powerfully when it first unites with the water. The manner of putting the bags into the acid is also important. They should not be held a foot or more above the jars and dropped in, as the bags may be thrown out by the reaction. Each bag must be carefully laid in the jar, but the fumigator must not lean over the jar as he does it, nor remain near it to watch the reaction. After a few fumigations the operator often becomes less attentive to the prescribed directions and precautions. This tendency should be promptly checked, the utmost care and caution being uniformly necessary.

CARBON BISULFID

Carbon bisulfid is used as a fumigant for aerial plant-lice, for root-lice and root-maggots, and for weevils in seeds. For methods to be followed in treating the first class mentioned, see page 112. For root-lice and root-maggots, a small hole is made in the ground near the plant, and into it is poured a small tablespoonful of the liquid. The hole is then promptly closed and the maggots are killed by the fumes. The carbon bisulfid should not be poured on the plant above ground nor directly on the roots. For weevils, the seed should be placed in a tight box or bin, space being left at the top for a pan or other shallow dish for the carbon bisulfid. This should be used at the rate of one ounce to 60 cubic feet of box space, and the box should be kept closed for 24 hours. The vapor given off, being heavier than air, descends, killing all insects present without injuring the seed.

As the fluid is inflammable, and its vapor, mixed with air, somewhat explosive, precaution should be taken never to permit a spark of fire to come in contact with it.

Carbon bisulfid may be obtained at drug stores for 20 to 35 cents a pound. A grade known as "Fuma Carbon Bisulphide," which is fully as effective for fumigation as the ordinary grade sold by druggists, is manufactured by E. R. Taylor, Penn Yan, New York, and furnished in 50- or 100-pound cans at 10 cents a pound.

SULPHUR

Thoro cleaning of greenhouses for the eradication of insect pests should be practiced by the greenhouse gardener when the houses are empty, and fumigating with sulphur is one of the best and easiest means to this end. About one pound of sulphur should be burned to every 2,000 cubic feet of space, after which the house should be kept tightly closed for 24 hours, or longer if convenient. It is needless to say that at this strength all plants, as well as insects, will be killed.

For fumigating houses containing growing plants, evaporate a small quantity of sulphur in a suitable receptacle over a lamp or oil burner, taking care that it does not catch fire; or the steam pipes may be painted with a sulphur paste made by mixing sulphur and water. A paste is sometimes made in which the sulphur is mixed with oil instead of water. Sulphur is not only valuable as an insecticide, but useful in controlling mildew.

TOBACCO STEMS

The tobacco stems for fumigation purposes have been largely superseded by the recent introduction of various nicotine extracts, they are still used, and are recommended for killing plant-lice and thrips, especially when easily obtainable at a reasonable price.

Three piles of stems, of about half a bushel each, are used to every 100 linear feet of the house, the piles being dampened to prevent rapid burning. These are set on fire in the evening, when the building is left for the night. The house must be kept as tightly closed as possible until morning. Frequent fumigations—at least weekly—are necessary to obtain the best results.

NICOTINE PREPARATIONS

Many nicotine preparations are now on the market under such trade names as "Nicoteen," "Nicoticide," "To-ba-ken," "Nico-Fume," etc. Most of them contain 25 to 45 percent of nicotine, and are more effective, tho more costly, than tobacco stems or tobacco dust. They may be used as fumigants in various ways. The com-

mercially prepared fumigating papers are suspended in strips and lighted when ready to fumigate. Dry preparations are placed in shallow dishes and ignited. It is sometimes advisable to add a few drops of kerosene to facilitate their burning. The extracts are evaporated over a lamp, or, like the sulphur paste, are painted on the steam pipes. They evaporate or burn slowly, producing a powerful vapor. As a rule it is best to fumigate in the evening, keeping the houses closed over night. Most insect pests of the greenhouse may be controlled by thoro and oft-repeated fumigations with one of these extracts.

ERRATA

Page 46, in legend for Fig. 51, for *ichneumoned* read *ichneumonid*.

Page 93, line 6, for *Agrotis* read *Eragrostis*.

Page 146, line 13, for *persica*, read *persicæ*.

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